Physical Activity, Sedentary Behaviour and Sleep in Adolescent Females in New Zealand

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Abstract

Background: Physical inactivity, sedentary lifestyles, obesity, and their associations with numerous adverse health outcomes are arguably the largest health concerns to children and youth. Historically, moderate-to-vigorous intensity physical activity (MVPA) is most commonly assessed in relation to health. However, physical activity is often the smallest component of 24 h activity, which includes light-intensity physical activity (LPA), sleep and sedentary behaviour (SB). New research suggests these activities in combination rather than isolation may help researchers better understand the health of specific populations, therefore potentially aiding the development of effective public health interventions.

Objective: The purpose of this study was to describe the 24 h activity patterns: sleep, sedentary behaviour, and light and moderate-to-vigorous intensity physical activity, measured in adolescent females of the SuNDiAL project.

Design: Adolescent females aged 15-18 y were recruited from 8 locations in New Zealand (NZ). Actigraph GT3X+ accelerometers and self-report wear-time diaries were used to identify time in sedentary pursuits, light-intensity physical activity, and moderate-to-vigorous intensity physical activity. Type and intensity of physical activity was determined using cut-points by Freedson, Melanson, and Sirard (1998). Sleep duration was identified using the Sadeh, Sharkey, and Carskadon (1994) algorithm constrained using self-reported bed-times from the daily sleep log.

Results: Participants spent half their time sedentary (50%), one-third sleeping (31%), 15% in LPA, and 4% in MVPA. On average, participants spent 49.1 minutes per day in MVPA, and 7.3 h per day sleeping. Approximately 23% and 27% of participants met the guidelines for sleep and MVPA, respectively. Those in the healthy body mass index (BMI) category were more likely to meet the guidelines than their overweight and obese counterparts. Time spent sedentary did not appear to differ across weight categories; however, overweight and obese participants spent less time in MVPA and sleep and more time in LPA.

Conclusion: Female adolescents spend the majority of their time sedentary. Approximately one in four meet either the sleep guidelines (8-10 h per day) or the physical activity guidelines (>60 min per day), and one in ten participants met both guidelines. These findings indicate the poor behavioural choices of this population and the need for more targeted effective public health interventions.

Keywords: physical activity, adolescent, sedentary behaviour, 24-hour activity, sleep.

Preface

This research was completed as part of the Survey of Nutrition, Dietary Assessment, and Lifestyles (SuNDiAL) project from the Department of Human Nutrition, University of Otago. The candidate conducted this thesis under the supervision of Dr Meredith Peddie, as a requirement of the Master of Dietetics (MDiet) programme. Primary investigators of the SuNDiAL project (Dr Meredith Peddie and Dr Jill Hazard, University of Otago) were responsible for study design, obtaining ethical approval, initial recruitment of participating schools and general oversight of the study. Dr Meredith Peddie processed accelerometer and diary data.

The candidate and data collection team (three MDiet candidates) worked together on:

- Development of a presentation for recruitment purposes.
- Participant recruitment and verbal and written participant communication.
- Taking anthropometric measures and two 24 h diet recalls.
- Distribution of accelerometers and wear-time diaries.
- Liaising with school staff, phlebotomists and SuNDiAL coordinators.

Individually, the candidate was responsible for the following:

- Taking nine initial 24-hour diet recalls, and nine secondary 24-hour diet recalls from participants at Kapiti College.
- Taking seven secondary 24-hour diet recalls from participants at Whangarei Girls School and entering these in FoodWorks (dietary assessment software).

- Completing a review on the literature on physical activity, sleep, and sedentary behaviour in adolescent females.
- Input into study design, questionnaires, recording forms, and study protocols.
- Data collection and entry of all 24 h diet recalls into dietary assessment analysis programme, FoodWorks.
- Input into statistical analysis.
- Tables and figures and interpretation of results.
- Disseminating findings and writing this thesis.

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List of Abbreviations

BMI	Body mass index
CI	Confidence interval
cpm	Counts per minute
CVD	Cardiovascular disease
h	hours
kg	Kilograms
kcal	Kilocalories
LPA	Light-intensity physical activity
MDiet	Master of Dietetics
MET	Metabolic equivalent of task
MOH	Ministry of Health
MVPA	Moderate-to-vigorous intensity physical activity
n	Number of participants
NCD	Non-communicable disease
NZ	New Zealand
PA	Physical activity
SuNDiAL	Survey of Nutrition, Dietary Assessment, and Lifestyles
SB	Sedentary behaviour
SD	Standard deviation
T2DM	Type 2 diabetes mellitus
WHO	World Health Organisation
y	Years

1 Introduction

Physical activity is a movement behaviour crucial to physical, emotional and cognitive health. Participation in regular physical activity is a well-established preventative measure for several non-communicable diseases (NCDs) such as cardiovascular disease (CVD), hypertension, type two diabetes mellitus (T2DM), and some cancers (Warburton, Charlesworth, Ivey, Nettlefold, & Bredin, 2010). However, despite extensive evidence highlighting the link with increased longevity, and improved health, global physical activity levels remain low, especially in adolescents (Guthold, Stevens, Riley, & Bull, 2019; Hallal et al., 2012; World Health Organisation, 2019). Continuation of physical inactivity and high sedentary behaviour could have detrimental effects in the future as lifestyle behaviours in youth track into adulthood (Hallal, Victora, Azevedo, & Wells, 2006; Telama et al., 2005)

Traditionally, physical activity research has focused on the effects of participation in moderate-to-vigorous intensity physical activity (MVPA), the behaviour that accounts for the smallest time proportion of each day, even in those who participate in the highest levels of physical activity. However, recently there has been a shift in focus to acknowledge the remaining hours of the 24 h day and how either alone, or possibly more appropriately, in combination, can affect health. Movement behaviours including sleep, sedentary behaviour, light-intensity physical activity (LPA), and MVPA account for a 24 h day and are co-dependent with one another, thus changes in time spent in one movement influences time spent in another.

In support of this shift, and in recognition of the small but growing level of evidence, in 2016, Canada developed 24 h movement guidelines for children and youth (Tremblay et al., 2016). The guidelines recommend (per day): sixty minutes of MVPA, eight to ten hours of sleep, and less than two hours sedentary screen time (e.g. TV or phone use).

Modern, technological advances and environmental changes have increased opportunities for sedentary behaviours, physical inactivity and poor sleep hygiene. In fact, in 2001, it was estimated that children were expending approximately 600 kilocalories less energy a day compared to 50 years ago (Boreham & Riddoch, 2001). Adolescence is a critical period of growth and development, yet adolescents are typically associated with high rates of physical inactivity and poor adherence to the physical activity guidelines (Colley et al., 2011; Troiano et al., 2008).

A shocking one in five adolescents worldwide are currently meeting the physical activity guidelines (Guthold et al., 2019; Hallal et al., 2012). Furthermore, females are less compliant than their male counterparts (Guthold et al., 2019; Hallal et al., 2012; Troiano et al., 2008). In studies of New Zealand (NZ) adolescents, using self-report (Ministry of Health, 2019), and accelerometer measurement of physical activity (Kek, García Bengoechea, Spence, & Mandic, 2019; Maddison, Turley, Legge, & Mitchelhill, 2010b), also found poor adherence to the guidelines. However, there has been minimal research on 24 h activity on adolescents in NZ, particularly females. Therefore, the purpose of this study was to describe the 24 h activity patterns: sleep, sedentary behaviour and physical activity, measured in NZ adolescent female participants from the SuNDiAL project.

2 Literature Review

2.1 Literature review methodology

Literature was sourced from the following online databases: Scopus, MEDLINE, Google Scholar, and included articles from 1985 to 2019. Key search terms included a combination of: ‘physical activity’, ‘moderate-to-vigorous physical activity’, ‘sedentary behaviour’, ‘sleep’, ‘24-hour behaviour’, ‘adolescent’, ‘female’, and ‘accelerometry’. Literature located within reference lists of identified articles was also used.

2.2 The 24-hour activity model

A good body of evidence suggests that each of the behaviours that make up a 24 h period (increased sleep, decreased sedentary time, and increased physical activity) are associated with disease prevention and overall health longevity (Cappuccio, Cooper, D'Elia, Strazzullo, & Miller, 2011; Haskell et al., 2007; Katzmarzyk, Church, Craig, & Bouchard, 2009). Research has examined these behaviours in isolation, but there is limited information on the relationship between movement behaviours in a 24 h period, and even less evidence for priority groups, specifically female adolescents aged 15-18 y. The four components of the 24 h movement model are discussed in more detail in the following sections: sleep (2.2.1), sedentary time (2.2.2), light-intensity physical activity (2.2.3.1) and moderate-to-vigorous intensity physical activity (2.2.3.2). An estimated percentage distribution of 24 h activity in children and youth is presented in ***Figure 2.1***.

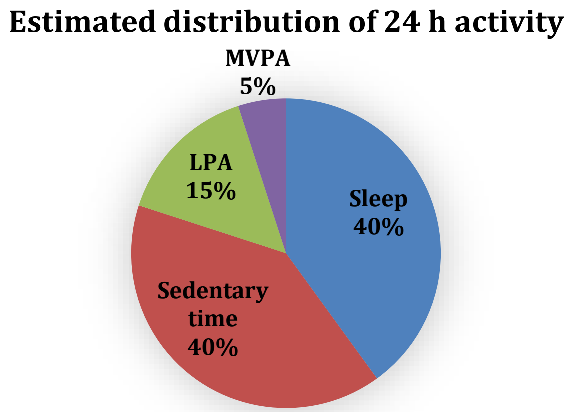

Figure 2.1: Estimated distribution of 24 h activity, adapted from Chaput, Carson, Gray, and Tremblay (2014)

2.2.1 Sleep

Sleep is an essential component of a healthy lifestyle, and a lack of sleep can pose a serious health risk to physical, social and emotional health (National Sleep Foundation, 2015). The recommended amount of sleep is 7-9 h for adults, and 8-10 h for adolescents (Ministry of Health, 2017; National Sleep Foundation, 2015). Poor sleep hygiene is one of the most commonly overlooked health problems and numerous countries have reported adolescents and adults very rarely obtain the recommended hours of sleep (Gradisar, Gardner, & Dohnt, 2011; Institute of Medicine Committee on Sleep Medicine and Research, 2006). Research shows sleep insufficiency (<7 hours per night) is associated with adverse health outcomes such as obesity, T2DM, and impaired glucose tolerance, CVD and hypertension, poor mental health symptoms and increased health care utilisation (Institute of Medicine Committee on Sleep Medicine and Research, 2006). There is evidence to suggest that not meeting the sleep guidelines is also associated with increased body mass in females (Krueger, Reither, Peppard, Burger, & Hale, 2015).

Table 2.1: Metabolic Equivalent scores for activity intensities.

Activity Intensity	MET score
Sedentary behaviour	1 – 1.5[1]
Low intensity physical activity	1.6 – 2.9[2]
Moderate intensity physical activity	3. – 5.9[2]
Vigorous intensity physical activity	>6.0[2]

1 Tremblay et al. (2017)
2 Ainsworth et al. (2011)

2.2.2 Sedentary time

Sedentary behaviour is most commonly described as a distinct class of behaviours performed in a seated position (e.g. watching TV, driving) characterised by little physical movement and low energy expenditure (<1.5 METs, Metabolic equivalent of a task) (Tremblay et al., 2017). Societal changes in NZ and globally have led to increases in sedentary time across many aspects of life including transport and entertainment (Hallal et al., 2012; Ng & Popkin, 2012). Over the past decade, substantial evidence has supported the relationship between high amounts of sedentary time, and increased mortality (Katzmarzyk et al., 2009; Rezende, Rodrigues Lopes, Rey-López, Matsudo, & Luiz, 2014), adverse health outcomes, particularly CVD (Katzmarzyk et al., 2009; Tremblay, Colley, Saunders, Healy, & Owen, 2010), some types of cancers (Howard et al., 2008; Tremblay et al., 2010), T2DM (Hu, Li, Colditz, Willett, & Manson, 2003), and reduced psychosocial health (Tremblay et al., 2010). Screen time such as television viewing is a component of sedentary behaviour which also is associated with increased risk of poor cardiometabolic health, T2DM, and obesity (Ekelund et al., 2016; Hu et al., 2003). In fact, television viewing is more strongly associated with an increased risk of mortality than total sedentary time (Ekelund et al., 2016). The increased accessibility and exposure to screen time and technology has prompted countries including NZ to develop a recommendation of no more than two hours per day of recreational screen time (Ministry of Health, 2017).

2.2.3 Physical activity

Physical activity can be defined as "any bodily movement produced by skeletal muscles that results in energy expenditure, measured by kilocalories (kcal) or kilojoules (kJ)" (Caspersen, Powell, & Christenson, 1985). It is a complex behaviour that includes energy expenditure from activity, occupation and leisure (exercise vs non-exercise). "Physical activity" and "exercise" are often used interchangeably; however, strictly speaking, exercise is a subcategory of physical activity in which the activity performed is planned, structured, and repetitive (Caspersen et al., 1985). Someone is usually considered to be "physically active" if they meet the physical activity recommendations of their country; otherwise, they are considered physically inactive (World Health Organisation, 2018). The intensity of physical activity is often defined in METs (metabolic equivalent of a task), which enables researchers to compare energy expenditure between different individuals. The MET value of each intensity of activity is presented in ***Table 2.1.***

2.2.3.1 Light physical activity (LPA)

Light physical activity involves energy expenditure between 1.6 to 2.9 METs and includes numerous non-strenuous day-to-day activities (slow walking, cooking, washing dishes) (Pate, O'neill, & Lobelo, 2008). Traditionally, it was believed only MVPA had health benefits, so LPA was often grouped with either sedentary time or MVPA, causing a gap in research and subsequently vague LPA recommendations. However more recently, LPA has been recognised as an individual component of 24 h activity that research indicates, may contribute to health (Carson et al., 2013; Tremblay et al., 2010; Tremblay, Esliger, Tremblay, & Colley, 2007). Although the energy cost of activities categorised as LPA is generally low, it is not uncommon for hours of LPA to accumulate across the day, therefore meaningfully contributing to total daily energy expenditure.

2.2.3.2 **Moderate-to-vigorous physical activity (MVPA)**

Moderate-intensity physical activity and vigorous-intensity physical activity are defined as energy expenditure between 3.1 to 6 METS, and >6METs, respectively (Ainsworth et al., 2011). They are commonly grouped together in guidelines and research because individually, they can account for a very small number of minutes. The majority of the literature to date has focused on the health benefits associated with participation in MVPA. Therefore the remainder of this thesis is specifically describing health benefits associated with physical activity overall (section 2.3) and specifically in adolescents (section 2.4). Followed by how much physical activity adolescents are currently participating in (section 2.5), and a summary of the methodologies currently used for the assessment of physical activity, alone (section 2.6), and in the context of a 24 h day (section 2.7).

2.3 Physical activity and health in adults

Globally, physical inactivity has increased dramatically and is now the fourth leading risk factor for mortality (World Health Organisation, 2010). There is a large body of evidence to support the link between regular physical activity, increased longevity, and a reduction in the risk of developing several chronic diseases such as CVD, T2DM, some cancers, hypertension and osteoporosis (Nocon et al., 2008; Reiner, Niermann, Jekauc, & Woll, 2013; Warburton et al., 2010; Warburton, Nicol, & Bredin, 2006; World Health Organisation, 2004).

A number of meta-analyses and systematic reviews of observational studies have reported the inverse relationship between physical activity and all-cause mortality in adults after adjusting for relevant risk factors (age, gender, smoking, blood pressure) (Löllgen, Böckenhoff, & Knapp, 2009; Nocon et al., 2008; Rey Lopez, Gebel, Chia, & Stamatakis, 2019; Samitz, Egger, & Zwahlen, 2011b; Woodcock, Franco, Orsini, & Roberts, 2010). Woodcock et al. (2010), found engaging in low levels of self-reported non-vigorous physical activity (<2.5 h/week) and high levels (>7 h/week) had a 19% (95% CI 15% to 24%) and 24% (95% CI 19% to 29%) reduction in risk of mortality respectively, compared to inactive individuals (0 h/week). Similarly, Samitz, Egger, and Zwahlen (2011a) compared those meeting MVPA guidelines (G1 =150 min/week; G2 = 300 min/week) with those who did not (G3 = <60 mins/week). A 14% (RR of 0.86; 95% CI 0.80 to 0.92), and 26% (RR of 0.74; 95% CI 0.65 to 0.85) risk reduction of all-cause mortality was reported in G1 and G2, compared to G3. Nocon et al. (2008) and Löllgen et al. (2009) described similar results with the majority of studies involved favouring the active groups compared to inactive groups.

A link between physical activity and a reduction in risk of CVD mortality and morbidity is evident (Nocon et al., 2008; Warburton et al., 2010). Nocon et al. (2008) included 33 cohort studies with a follow-up period of 4 to 20 y. The majority of included studies reported a 30 to 50% risk reduction of CVD mortality in physically active individuals compared to their inactive counterparts, with a 35% overall pooled reduction in risk (combined RR 0.65, 95% CI 0.60 to 0.70). Interestingly, studies using fitness tests compared to self-report methods reported a 57% (RR 0.43, 95% CI 0.33 to 0.57) and 30% (RR 0.70 (95% CI 0.60 to 0.70) risk reduction, respectively. This was possibly due to overestimations of true physical activity levels in self-reports, which, as a consequence, minimised the correct protective effect (Nocon et al., 2008).

Compared to other non-communicable diseases (NCDs), there is less literature about the role of physical activity in the prevention of T2DM. Several systematic reviews and meta-analyses suggest an inverse relationship between T2DM and physical activity, and report inactive individuals are 30 to 50% more likely to develop T2DM than their active counterparts (Aune, Norat, Leitzmann, Tonstad, & Vatten, 2015; Warburton et al., 2010). An estimated quarter of cancer incidence is related to physical inactivity and obesity. In particular, physical activity is associated with a 40% and a 20 to 40% risk reduction in breast and colon cancer, respectively (International Agency for Research on Cancer, 2002). Warburton et al. (2010) reported similar results, stating a 20 to 40% and 30% risk reduction in breast and colon cancer, respectively, in active vs non-active individuals.

2.4 Physical activity and health in adolescents

Adolescence is arguably the most critical period for the prevention of chronic disease as lifestyle behaviours may set healthy patterns for adulthood (Hallal et al., 2006; Telama et al., 2005). In fact, there is evidence to suggest physical activity in adolescence is a contributing factor to adult physical activity patterns (Azevedo, Araujo, Cozzensa da Silva, & Hallal, 2007; Hallal et al., 2006; Telama et al., 2005). Chronic diseases generally manifest in adulthood, and the long time frame associated with the development of these means the relationship between physical activity and disease incidence in adolescents is not well studied. However, research on the effects of adolescent physical activity on risk factors for these NCDs is more common. Evidence suggests physical activity is necessary for healthy growth and development, and for the improvement of numerous health outcomes including more favourable cardiometabolic clustered risk scores, enhanced respiratory fitness and muscular strength, improved body composition, better bone health and improved psychological well-being (Janssen & LeBlanc, 2010; Poitras et al., 2016). These associated health benefits lead to overall improved health and reduction in the risk of mortality and morbidity of several NCDs (Warburton et al., 2010).

Cardiometabolic risk factors commonly include high blood pressure (systolic and diastolic); elevated blood lipids (total cholesterol, HDL cholesterol, and triglycerides); and increased insulin resistance. Associations between adolescent physical activity and these risk factors in isolation is somewhat inconsistent, and CVD is generally not characterised by one marker, therefore, focusing on a clustered risk score may provide a more adequate prediction of future disease risk (Wilson et al. 1998).

Table 2.2: Physical activity and cardiometabolic risk score in adolescents

Author/date	Study/Participants	Measurement of PA	Results
Cristi-Montero et al. (2019)	HELENA study conducted 2006-2008, n =3528 aged 12.5-17.5 y.	Hip-worn Actigraph accelerometers during waking hours for 7 days.	Active adolescents with low levels of sedentary behaviour had significant reductions in clustered cardiometabolic risk score, compared to inactive sedentary adolescents (pvalue <0.001). As did active adolescents with high sedentary behaviour (pvalue<0.01).
Tarp et al. (2018)	International Children Physical Activity Database (ICAD), n= 29,734, 4-18 y.	Waist-worn Actigraph accelerometers for 4-7 days.	Higher physical activity levels were associated with better clustered cardiometabolic risk profiles. Increasing activity, particularly at higher intensities was associated with lower risk scores.
Mendoza, Nicklas, Liu, Stuff, and Baranowski (2012)	NHANES 2003-2004 and 2005-2006, n=2155, 6-19 y.	Hip-worn Actigraph accelerometers for 7 days.	Adherence to the MVPA guidelines was significantly associated with lower clustered metabolic risk score (pvalue<0.039).
Andersen et al. (2008)	EYHS cross-sectional study including n=1769 randomly selected 9 & 15 year old's.	Actigraph accelerometers were worn for 4 consecutive days.	(Q1 = lowest PA and Q4= highest PA). After adjusting for fitness and fatness, there was an association between PA and clustered risk (Odds ratio of 1.30, 2,45, and 2.10 for Q3, Q2, and Q1 compared to Q4, respectively).
Butte, Puyau, Adolph, Vohra, and Zakeri (2007)	VIVA LA FAMILIA study 2000-2004, n=897 non-overweight & overweight Hispanic youth, 4-19 y.	Actiwatch accelerometers for >3 days and self-report questionnaires.	Metabolic syndrome was not significantly related to physical activity. However, number of components of the metabolic syndrome was significant for activity counts (OR=0.98, p value =0.03), and for 5 minute bouts of MVPA (OR=0.94, p value =0.02).

Ekelund et al. (2006)	EYHS study, n=1921, 9-10 y & 15-16 y.	Hip-worn Actigraph accelerometer for 4 days during waking hours.	After adjustment for television viewing and adiposity, PA was significantly associated with a lower metabolic risk score (p value <0.0001).

Abbreviations: PA= physical activity. MVPA= moderate-to-vigorous physical activity. n= number of participants. HELENA= Healthy Lifestyle in Europe by Nutrition in Adolescence. NHANES= National Health and Nutrition Examination Survey. EYHS = European Youth Heart Survey.

In light of this, several studies assessed physical activity in children and adolescents and clustered risk scores (calculated using a summed z-score of individual risk factors including systolic blood pressure, triglycerides, total cholesterol/HDL cholesterol ratio, HOMA (homeostatic model assessment) score and aerobic fitness). As summarised in ***Table 2.2***, those engaging in more physical activity have decreased clustered risk compared to less active individuals. Overall, being physically active in adolescence is associated with lower CVD risk. More favourable cardiometabolic profiles in adolescence is linked to more favourable cardiometabolic profiles in adulthood (Twisk, Kemper, & Van Mechelen, 2002).

2.4.1 Body Mass Index (BMI) and physical activity in adolescents

Body mass index in youth is age- and sex-specific and therefore BMIs in this age group are categorised as healthy, overweight or obese according to z-scores (de Onis et al., 2007). It is believed variation in physical activity levels among adolescents is an important contributor to weight status and therefore BMI group. Research shows, after adjusting for confounders including race, age, and sexual maturity, weight in adolescent females is inversely related to accelerometry-measured physical activity (Chung, Skinner, Steiner, & Perrin, 2012; Sulemana, Smolensky, & Lai, 2006).

2.5 Adolescent physical activity guidelines

Historically, healthy children (5-11 y) and adolescents (12-17 y) were recommended to obtain at least 60 min/day of MVPA (World Health Organisation, 2010). In 2016 the Canadian Society for Exercise Physiology released integrated 24 h movement guidelines recommending a balance of sufficient sleep (9-11 h for 5-13 y and 8-10 hr for 14-17 y), low levels of sedentary behaviour (<2 h recreational screen time), and high levels of physical activity (60+ min/day MVPA, which should include muscle-strengthening activity at least 3 days a week)(Canadian Society for Exercise Physiology, 2016). These guidelines were subsequently adopted by New Zealand (Ministry of Health, 2017) and Australia (Australian Government Department of Health, 2018).

2.5.1 How much physical activity are adolescents doing?

Despite the known importance of physical activity and development of interventions pushing for population-level engagement, over the past fifteen years, the prevalence of physical inactivity in adolescent girls has remained the same (Guthold et al., 2019). Globally, it is estimated only one in five (20%) of adolescents meet the physical activity guidelines, including 22% of boys and 15% of girls (Guthold et al., 2019). As summarised in ***Table 2.3***., Australia, the United States, Canada, South Africa, and numerous other European countries, have reported that adolescents appear to be doing approximately 20 to 55 min of MVPA per day. Additionally, between 0 to 41% of adolescents are adhering to the physical activity guidelines. Disparities in results likely reflect true differences in rates of physical activity between countries, but may also be influenced by different methods of assessing physical activity.

Table 2.4 summarises three NZ studies measuring physical activity in adolescents. However, one study used self-report physical activity data (Ministry of Health, 2019), another used an unpublished governmental report with limited methodology (Maddison, Turley, Legge, & Mitchelhill, 2010a), and the last used a younger population (13-14 y) from a single site (Kek et al., 2019). They indicated approximately 44 to 55 minutes per day was spent in MVPA, and interestingly males spent more time in MVPA than their female counterparts (55 min compared to 36 min respectively). Between 30 and 40% of adolescents met the physical activity guidelines. Females were less likely than males to meet the guidelines in all three studies. This data highlights a gap in the research and that very little is known about female adolescents activity in NZ. Furthermore, there is no current research in NZ assessing MVPA in combination with other 24 h movements (sleep, sedentary behaviour, and LPA) in adolescent females.

Table 2.3: MVPA minutes per day and prevalence (%) of those meeting the physical activity guidelines globally

Author/date	Study design	Participants	Measurement of PA	MVPA (min/day)	Prevalence (%) of meeting PA guidelines
Hanson et al. (2019) **South Africa**	Longitudinal study called the Birth-to-Twenty Plus Cohort.	n=1414 children/youth, 12-17 y.	Validated self-report questionnaire, (Organized sport was considered a proxy for MVPA per day).	N/A	18% of males and 0% of females. Although 11% of females participated in organized sport, none met the guidelines for duration.
Guthold et al. (2019) **146 countries**	Cross-sectional survey data from 298 surveys in 146 countries, 2001-2006.	n=1,600,000 students aged 11-17 y.	Validated self-report surveys from WHO or multi-country surveys.	N/A	81% (95% CI 77.8 to 87.7) of adolescents aged 11-17 y did not meet the PA guidelines. Males = 77.6% (95% CI 76.1 to 80.4) vs females=84.7% (95% CI 83.0 to 88.2).
Smith, Berdel, Nowak, Heinrich, and Schulz (2016) Germany	GINIplus and LISAplus 1995-1999 (15 y follow up).	n=1403 adolescents with a mean age of 15.6 y.	Hip-worn Actigraph GT3X+ during waking hours for 7 consecutive days between 2011-14.	Overall, males spent 45.4 min per day in MVPA, vs females 37.6 min per day.	Overall, only 6 males (0.92%) and 8 females (1.06%) met the PA guidelines.
Australian Bureau of Statistics (2013)	2011-2013 Australian Health survey.	n=32000, adults and children, 2-17 y.	Self-reported data (parents answered for those <15 y).	Males 45 min/day vs females 30 min/day of MVPA.	7.9% met the PA guidelines. 8.4% (males) vs 7.2% (females), aged 13-17 y.
Colley et al. (2011) Canada	2007-09 Canadian health measures survey.	n=1608 males and females, 6-19 y.	Hip-worn Actical Accelerometer on the right hip during waking hours for 7 consecutive days.	On average, 15-19 y olds spent 53 min/day (males) and 39 min/day (females) in MVPA.	6% (males) and 2% (females) met the PA guidelines >6 days/week (15-19 y), vs 45% (males) and 25% (females) at least >3 days/week.

Ruiz et al. (2011) 9 European Countries	HELENA cross-sectional study 2006-2008.	n=2200 adolescents, 12.5-17.49 y.	Lower-back-worn Actigraph GT1M accelerometer during waking hours for 7 consecutive days.	55 min/day in MVPA (males=64 min/day vs females=49 min/day)	Overall, 41% met the PA guidelines (males=56.8% vs females=27.5%)
Troiano et al. (2008) United States	NHANES representative cross-sectional study 2003-2004.	n=6329 males and females, 12-19 y.	Hip-worn Actigraph accelerometer during waking hours for 7 days.	16-19 y old's spent 32.7 min/day (males) vs 19.6 min/day (females) in MVPA/day.	7.6% of 16-19 y old's met the PA guidelines (males=10% vs females=5.4%).

Abbreviations: PA= physical activity. MVPA= moderate-to-vigorous physical activity. n= number of participants. y= years. CI= confidence interval. N/A= not applicable. HELENA= Healthy Lifestyle in Europe by Nutrition in Adolescence. NHANES= National Health and Nutrition Examination Survey.

Table 2.4: MVPA minutes per day and prevalence (%) of those meeting the physical activity guidelines in NZ adolescents

Author/date	Study design	Participants	Measurement of PA	MVPA	Prevalence (%) of meeting PA guidelines
Kek et al. (2019)	A sample from the BEATs Study 2014-2015.	n=314, aged 12-18 y from Dunedin secondary school.	Right hip-worn Actigraph GT3X+ accelerometer during all hours for 7 days and a self-report diary.	On average 55.8 min/day in MVPA.	39.2% of participants adhered to the physical activity guidelines. Specifically, 45.6% of males and 36% of females.
Ministry of Health (2019)	Multi-stage sampling design. Representative sample.	n=13869 adults and 4723 parents of children in New Zealand.	Self-reported physical activity. MVPA was for bouts of 10 minutes at a time. Those who achieved >5 h/week of MVPA were classified as physically active.	N/A	Approximately 40.6% of 15-17 y olds were classified as physically active (37.3% women vs 43.6% men).
Maddison et al. (2010b)*	Representative survey.	Representative sample of n=2503 children and young people (5-24 y).	Data was collected using a validated computerized 24h recall questionnaire (MARCA) and Actigraph accelerometers were worn on the hip for 7 consecutive days.	45.9 min/day in MVPA(15-19 y), Males (55 min/day) vs females (36 min/day).	The proportion 15-19 y olds that met the PA guidelines were 49%, 33%, and 32.3% of men, women and total adolescents, respectively.

** Studies that included 18+ y old's and compared them to the adult guidelines.*
Abbreviations: PA= physical activity. MVPA= moderate-to-vigorous physical activity. n= number of participants. y= years. N/A= not applicable.

2.6 Measuring physical activity

Physical activity generally consists of three dimensions: 1) intensity (light, moderate, and vigorous); 2) frequency (amount of sessions); and 3) duration (time). The context (e.g. leisure, transport, school physical education) and the mode of physical activity (e.g. cycling, swimming, running) are additional components. These are often captured using methods such as direct observation, self-report methods (e.g. diaries), or devices (e.g. accelerometers). All methods present challenges with validity, reliability and ease of administration; therefore, the ideal method must be matched to the researchers intended outcomes.

2.6.1 Self-report measurement

Self-report methods include self-administered or interviewer-administered questionnaires or diaries. These ask participants to recall the specific type of, or total amounts of physical activity (Sallis & Saelens, 2000). They are cost-effective and able to collect varying data from large populations such as the type, duration, location and mode of activity (Warren et al., 2010). No equipment is needed, and it is less burdensome on both the participants and the research team. However, self-report measures are subject to recall bias, especially in adolescent populations (Biddle, Gorely, Pearson, & Bull, 2011; Sallis & Saelens, 2000), as intensity of physical activity is often overestimated (Leblanc & Janssen, 2010). Social desirability may impact results, as fear of judgement can push participants to report perceptions of activity rather than actual activity (Sallis & Saelens, 2000). Questionnaires also require participants to be literate and numerate to answer the questions accurately.

2.6.2 Direct observation measurement

Direct observation allows researchers (as an objective third party) to observe and record physical activity as it occurs, minimising the potential for recall bias (McKenzie, 1991).

Consequently, researchers and or video cameras are required to be in the same environment as subjects (i.e. a classroom), and physical activity must be able to be coded (McKenzie, 1991). It is costly, highly labour intensive, and requires trained observers (Dollman et al., 2009). The obtrusive nature of this method makes it a rare choice for physical activity measurement. The presence of the researcher observing or filming may result in participant behaviour modification and therefore, not a realistic representation of usual activity patterns (Armstrong & Welsman, 2006).

2.6.3 Device measurement of physical activity

2.6.3.1 Pedometers

Pedometers are small devices that measure step counts and or the distance travelled (Armstrong & Welsman, 2006). They are predominantly used in large scale studies for their simple, cheap and non-obtrusive nature (Ainslie, Reilly, & Westerterp, 2003). Pedometers record short bursts of physical activity that self-report measures often miss; however, they cannot measure intensity, frequency, and patterns of physical activity (Armstrong & Welsman, 2006). Like all devices specifically for measurement of activities, pedometers can cause participant reactivity and therefore overestimate usual physical activity (Rowlands & Eston, 2007).

2.6.3.2 Accelerometers

Accelerometers are quickly becoming the most commonly used method of measuring physical activity and sedentary behaviour due to their ability to assess frequency, intensity and duration (Freedson & Miller, 2000). The small motion-sensors are generally worn on the hip, wrist, or thigh and process raw acceleration into 'counts' which allow researchers to determine energy expenditure and therefore distinguish between time spent in different intensities (Ridgers & Fairclough, 2011). The newer models in particular, have gained popularity from their accuracy, ease of use and capacity to hold several days and weeks of data (Trost, McIver, & Pate, 2005). They also prohibit participants from gaining feedback about data collected which limits physical activity modification and reactivity, providing a more representative measure (Sirard & Pate, 2001). Accelerometry can provide a realistic and habitual picture of adolescent physical activity compared to other methods as it can record small bursts of activity, commonly seen in children and adolescents (Rowlands & Eston, 2007). However, it is not without its challenges. They are unable to give contextual information about place and mode of activity. Additionally, there is no standardised method of data processing and interpretation (Troiano, 2005), and hip or thigh positioning often prohibits the correct identification of intensity of activities performed by the upper body only (Warren et al., 2010). Researchers must make critical decisions regarding the use of the accelerometer including the type of monitor used, the positioning, how wear-time and non-wear time are differentiated, and the data storage epoch length (Trost et al., 2005; Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005). Each factor can consequently affect data collection and results.

The Actigraph GT3X+ is the most commonly used accelerometer for measuring physical activity. Compared to older models, it is triaxial (measures acceleration in three planes), light, water-resistant and has a large data storage (Santos-Lozano et al., 2013). When used to primarily detect physical activity, devices are positioned closest to the centre of mass, specifically the hip or lower back (Ridgers & Fairclough, 2011), but the majority of comparative studies highlight that hip-based placement provides the most accurate data (Trost et al., 2005; Ward et al., 2005). When used primarily for sleep, they are often positioned on the wrist (Sadeh et al., 1994). Collected data can be stored in epochs of 15, 30, or 60 seconds that are used to estimate time spent in various intensities. For the measurement of physical activity in children and adolescents, it is recommended that devices be worn consecutively for between 4 to 9 days as differences often occur between weekdays and weekends (Trost et al., 2005), and saved as the shortest epoch to capture short bursts of physical activity commonly seen in this age group (Ward et al., 2005).

2.7 Measuring physical activity as part of a 24 h day

Traditionally, the different components of the 24 h day (sleep, sedentary time and physical activity) were measured in isolation – for example sleep was measured by polysomnography in a sleep laboratory, and then the associations between sleep duration or sleep quality and BMI were investigated, without attempting to quantify physical activity or sedentary time. New technology such as small wearable devices have made it possible to use a single device to capture every component of a 24 h day in a free-living environment (Aadland & Ylvisåker, 2015; Arvidsson, Fridolfsson, & Börjesson, 2019).

2.7.1 Sedentary behaviour, LPA and MVPA

The Actigraph GT3X+ is currently one of the only devices with the ability to measure all four components of the 24 h day (Rosenberger, Buman, Haskell, McConnell, & Carstensen, 2016). This allows researchers to look at each component individually, in comparison with each other, and in comparison with the recommended guidelines. Cut-off points are applied to accelerometer output to categorise various intensities of physical activity. The accuracy of the cut-off points is possibly the most important step to getting a true representation of physical activity; however, there is no current consensus on the best cut-points for children and adolescents (Howe, Clevenger, Leslie, & Ragan, 2018; Kim, Beets, & Welk, 2012). This age group is likely to be most physically similar to the young adults used to create the adult cut-points such as those from Freedson et al. (1998). Using adult as opposed to child cut-points may provide the most accurate representation of habitual physical activity in this age group.

2.7.2 Measuring sleep

Polysomnography is a sleep test that monitors sleep-wake states and physiological measures including brain dynamics, eye movements, muscle activity and respiratory function (Marino et al., 2013). It is currently gold standard, although it is expensive and time-consuming (Marino et al., 2013). Alternatively, Sadeh (2011) has validated an algorithm to identify sleep from wrist-worn accelerometers. Kinder et al. (2012) has found that this algorithm is also accurate using hip-worn accelerometers if participants supply a diary of events (bed-time/wake-up time, etc.). Additionally, hip-worn accelerometry data provides a more accurate measurement of physical activity (Trost et al., 2005).

2.8 Summary

Physical activity plays an important role in the reduction in risk of mortality and morbidity. Despite this, current literature provides a sobering image of the low rates of physical activity globally, particularly among adolescent girls (Guthold et al., 2019). Recently, research has recognised physical activity as one component of a 24 h day that also includes sleep, sedentary time, and light physical activity, all of which affect health individually, but possibly more importantly, in combination with each other. Very few studies have described the physical activity levels of NZ adolescent females. The most recent study only reported time spent in moderate-to-vigorous physical activity. Therefore, despite the adoption of the 24 h guidelines in 2017, we currently have a very limited, if any, understanding of the 24 h activity patterns of adolescents.

3 Objective statement

The aim of this study is to measure the 24 h activity patterns: sleep, sedentary behaviour and physical activity, of a nationwide sample of New Zealand adolescent females.

The objectives of the study are:

- To measure the amount of time is spent in sleep, sedentary behaviour, light-intensity physical activity, and moderate-to-vigorous intensity physical activity over 24 h.

- To compare between BMI categories the time spent in sedentary behaviour and light-intensity physical activity.

- To compare between BMI categories the prevalence of participants meeting the sleep and MVPA guidelines.

4 Subjects and Methods

4.1 Overall study design

Data reported in this thesis was collected as part of the larger SuNDiAL (The Survey of Nutrition, Dietary Assessment and Lifestyles) Project. The study was a cross-sectional survey of female adolescents in New Zealand (NZ). The main aim of this study was to compare the dietary intakes and habits, nutritional and health status, motivations, attitudes, and lifestyles of vegetarian and non-vegetarian adolescent (aged 15-18 y) females in NZ. This thesis describes the 24 h activity patterns: sleep, sedentary behaviour and physical activity, measured in a subsample of participants of the SuNDiAL project who consented to wear accelerometers.

4.2 Participants

4.2.1 Recruitment of schools

Female adolescents were targeted using school-based recruitment. Initially, a list of schools to contact was created for each predetermined data collection area in which schools with larger female roles (<200) and lower decile (a measure of the socio-economic status of the school) were given priority. These schools were contacted via email, then followed up via phone call or email two weeks later to assess interest. If interest was shown, suitability of dates and times for data collectors (MDiet students) to enter the school was discussed, as well as facilities and spaces available for data collection. If these emails failed to secure a school or schools in a target area, word of mouth was used to secure a school in that location. At the end of the first phase of recruitment (February – June 2019) it was identified that a lower number of vegetarians than anticipated had enrolled in the study, therefore targeted recruitment methods were used in the second phase (July to September 2019) to recruit additional vegetarian female adolescents in Dunedin only.

4.2.2 Recruitment of participants

Data collectors visited participating schools in the area they were based and presented to girls aged 15-18 y using an electronic presentation, a recruitment video and distributed printed information. Adolescent females who were interested provided their email address directly to the data collectors, or signed up online. These girls were then sent a link to the online REDCap (production server version 9.3.3) questionnaire in which participants provided informed consent. Additionally, guardians of those <16 y were asked to provide informed consent via email. Participants answered three questionnaires regarding demographics and health, as well as questions on attitudes, motivations, and beliefs about food choices.

4.2.3 Eligibility criteria

The inclusion criteria for the SuNDiAL study were 15 to 18 y of age, self-identified as female, attending a secondary school in NZ which had agreed to be a participating school, or had been recruited as a vegetarian in Dunedin only. Participants were not eligible if they were unable to speak and understand English, and if they knew they were pregnant.

4.2.4 Ethics

The study was approved by the University of Otago Human Ethics Committee (Health):H19/004 (**Appendix A)**. Online informed consent was obtained from all participants and from parents/guardians of those under 16 y. The trial was registered with the Australian New Zealand Clinical Trials. Registry: ACTRN12619000290190.

4.3 Measurement procedures

4.3.1 Anthropometry

Bodyweight (BW) was measured in duplicate with the participant wearing light clothing, but no footwear, using bodyweight scales (one of Medisana PS420; Salter 9037 BK3R; Seca Alpha 770; or Soehnle Style Sense Comfort 400) and recorded to the nearest 0.1 kg. Height was measured to the nearest millimetre using either a Seca 213 or a Wedderburn stadiometer. Ulna length was also measured on the non-dominant side with the hand resting on the opposite shoulder. Measurements were taken between the point on the wrist bone and the point of the elbow using a tape measure. All measurements were taken in duplicate, and a third measurement was taken if any of the duplicate measures were more than 0.5 units apart. Data collectors were trained using published protocols (Ministry of Health, 2008; NIHR Southampton Biomedical Research Centre, 2019) and study protocols **(Appendix B)** to measure anthropometry. Prior to data collection, an inter-rate reliability study was performed to ensure consistency between data collectors. A convenience sample of 12 girls aged between 15-18 y consented to have anthropometric measurements taken. Data collectors measured each girl twice and inter-rater reliability was assessed using mixed-effects intra-class correlation coefficients (ICC). ICC for weight was 1.00, height was 0.92, and ulna length was 0.86, indicating high consistency between data collectors. Body mass index (BMI) was calculated by weight (in kg) divided by height (in m) squared. BMI z-scores for age and sex were calculated using the WHO child growth standards (de Onis et al., 2007).

4.3.2 24-hour dietary intake recall

Two non-consecutive twenty-four-hour diet recalls were performed with each participant using a three-pass method, once with data collectors during school hours and again by video or phone call on the following weekend to capture dietary intake variation. Participants were questioned about intake from midnight to midnight of the previous day using food models, photographs and household measures to prompt about quantities, brand and cooking methods. Each recall was entered in Foodworks9 (Xyris Software Australia Pty Ltd) by data collectors to allow calculation of energy, macronutrients and micronutrients. Dietary intake estimates were adjusted for 'usual intake' using the Multiple Source Method (MSM) (Harttig, Haubrock, Knüppel, & Boeing, 2011).

4.3.3 Accelerometry and wear-time diaries

Twenty-four hour activity was measured using Actigraph GT3X+ accelerometers (Actigraph LLC Pensacola, FL, USA) and self-report wear-time diaries. Accelerometers were worn on an elasticated belt over the right hip continuously for 24 h a day for seven consecutive days. Verbal instructions for accelerometer wear were given to participants, and detailed instructions can be found in the study protocol (***Appendix B***). Participants were instructed to remove accelerometers during showering, swimming and for high contact sports such as rugby. Sleep and wear-time diaries (***Appendix C***) were provided to promote compliance and capture self-reported bed and wake times. Participants were asked to record accelerometer removal times and reasons, and descriptions, durations and self-reported intensities of any activity not recorded by the accelerometer. The seven-day diary included a daily sleep log, instructing participants to record sleep patterns including the time they got in bed, time they attempted to sleep, time it took to fall asleep (min), as well as time they woke up and time they got out of bed.

4.4 Data processing and analysis

4.4.1 Wear-time

Time when the participant reported wearing the accelerometer in the wear-time diary was defined as 'wear-time'. Days were only considered valid if wear time during waking hours totalled 10 h or more. A participant's data was only included in the analysis if there were at least three valid days of data available.

4.4.2 Data processing

Accelerometers and wear-time diaries were returned to the research team at the University of Otago, and data was downloaded using Actilife software (Actigraph, Pensacola, Florida. Version 6). It was saved in 15-second epochs to capture short bursts of physical activity, then converted to csv file and assessed using Stata (*Stata Statistical Software: Release 16*. College Station, Texas: StataCorp). Time spent sedentary was classified as less than 150 counts per minute (cpm) using the y-axis. Time spent in LPA and MVPA was identified using a threshold of 150 to 1951 cpm and at least 1952, respectively, using the y-axis thresholds (Freedson et al., 1998). Time spent asleep was identified using the Sadeh algorithm (Sadeh et al., 1994), constrained by bedtimes reported from wear-time diaries. Any physical activity completed when the participant was not wearing an accelerometer was identified as 'non-wear time physical activity'. Non-wear time physical activity was added to the amounts of wear time MVPA and LPA depending on the self-reported intensity, to give total MVPA and LPA.

4.5 Statistical considerations

4.5.1 Sample size and statistical power

The sample size of this study was determined based on the primary outcome of describing differences between vegetarians and non-vegetarians. A sample size of 300 high school students enrolled from 14 high schools gave 80% power to the α=0.05 level to detect a 0.5 standard deviation difference (a “moderate” difference) in any continuous outcome variables between vegetarians and non-vegetarians, assuming a prevalence of vegetarianism of 20% and a design effect (for school clusters) of 1.5.

4.5.2 Statistical Methods

Participant anthropometric, demographic characteristics and all analyses were carried out using excel (Version 16.30). Mean time spent in each category of sleep, sedentary time, LPA, and MVPA was calculated and expressed as a percentage of total time. Additionally, time spent in each 24 h activity was expressed as mean time and standard deviation for three BMI categories (healthy, overweight, and obese). Prevalence of those meeting the sleep and physical activity guidelines were calculated for each BMI category and expressed as a percentage.

5 Results

Figure 5.1 represents the flow of participants. One hundred and sixty nine participants wore and returned accelerometers. Those who had instrument malfunctions, did not return wear-time diaries, and had <3 days of valid data were excluded from the analysis (n=34). Data from 135 participants were included in the analysis.

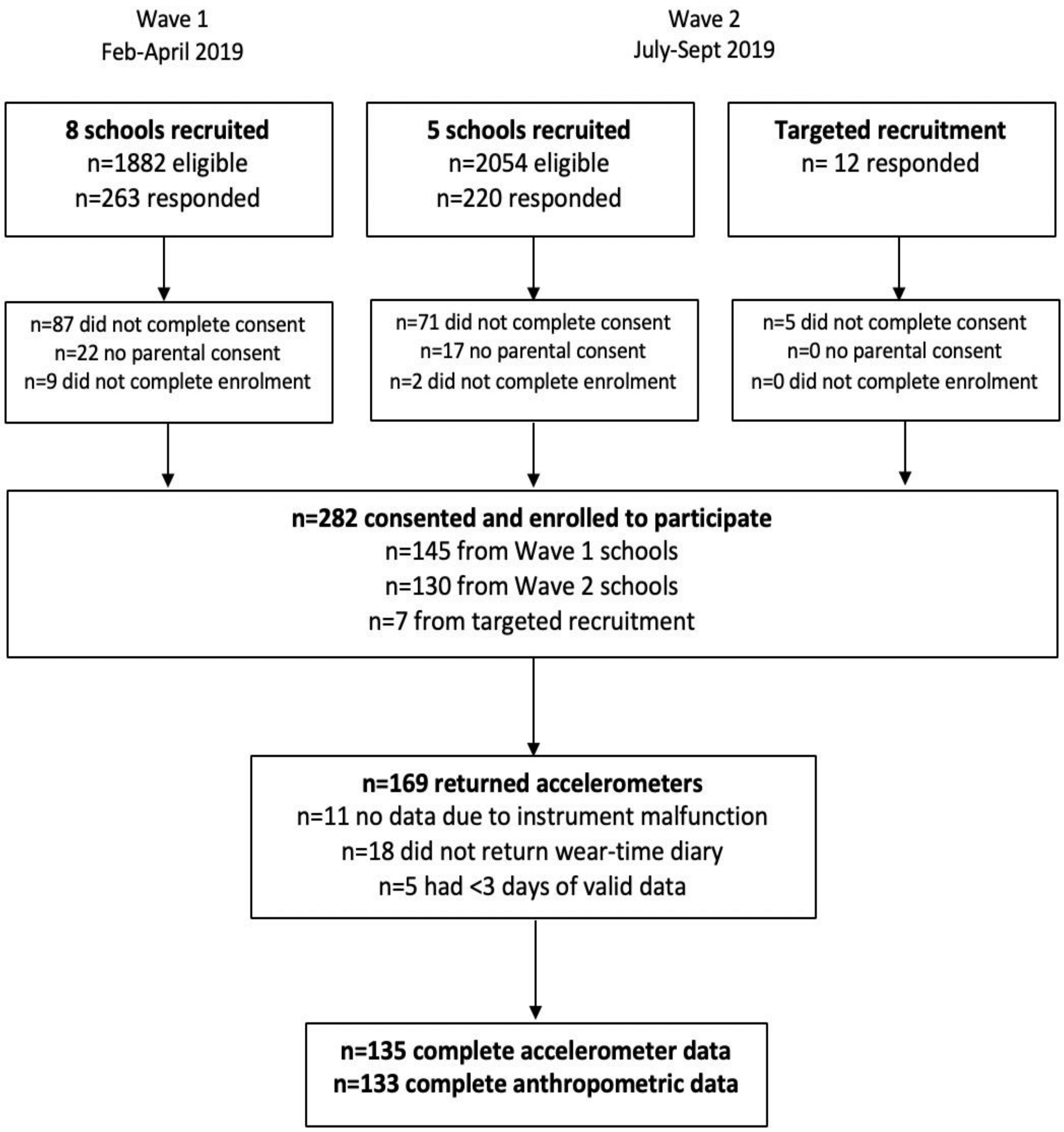

Figure 5.1: Study design and representation of participants through the study

5.1 Demographics:

Table 5.1: Anthropometric and demographic characteristics of participants with valid accelerometer data (n=135)

Characteristics	Participants (n=135)
Demographics	
Age, years, mean (range)	16.8 (15.0-18.8)
Height, cm, mean (SD)	165.6 (6.8)
Weight, kg, mean (SD)	65.1 (12.0)
BMI Category n (%)[1]	
Underweight	0 (0.0)
Healthy Range	90 (67.2)
Overweight	33 (24.6)
Obese	11 (8.2)
Ethnicity, n (%)	
New Zealand European or Other[2]	115 (85.2)
Maori	14 (10.4)
Pacific[3]	3 (2.2)
Asian[4]	3 (2.2)
NZ Dep, n (%)[5]	
1-3 (low)	44 (33)
4-7 (medium)	68 (50)
8-10 (high)	23 (17)

Abbreviations: n= number of participants, kg/m^2 = kilograms per metres squared, sd=standard deviation
[1] *Categorisations made based on BMI for age and sex z-scores (de Onis et al., 2007)* [2] *New Zealand European, Ethiopian, Somali, Italian, American, Nicaraguan, Irish, Afrikaans, Dutch, German, South African, Middle Eastern, Russian, Zimbabwean* [3] *Tokelau, Fijian, Cook Island, Samoan* [4] *Filipino, Japanese, Indian, Korean, Indonesian, Malay.* [5]*Derived from NZ Index of Deprivation (Ministry of Health, 2014).*

5.2 Total time spent in each activity

Wear-time (accelerometry), non-wear time (self-reported), and total time for each component of 24 h activity is presented as a mean and standard deviation (SD), in hours or minutes, in ***Table 5.2.*** The highest mean time spent in a category was sedentary time, followed by sleep, LPA, then MVPA.

Table 5.2: Mean daily wear-time (accelerometry), non-wear-time (self-report), and total time of adolescent females aged 15-18 y in sleep duration, sedentary time, LPA, and MVPA

Measure	**Wear time**	**Non-wear time**	**Total**
24 h activity[1]			
Sleep, hours[2]	7.3 (1.4)	N/A	7.3 (1.4)
Sedentary time, hours[3]	11.5 (1.8)	N/A	11.5 (1.8)
LPA, hours[3]	3.6 (1.1)	0.03 (0.1)	3.6 (1.2)
MVPA, minutes[3]	34.8 (17.3)	0.25 (0.5)	49.1 (32.7)
Total time, hours[1]	22.5 (1.8)	0.4 (0.2)	22.9 (1.9)

[1] *Mean (SD).* [2] n=133, as three participants did not wear the accelerometer overnight. [3] n=136.

Abbreviations: n= number of participants, LPA=light physical activity, MVPA= moderate to vigorous physical activity.

5.3 Percentage of the day spent in each activity

The total percentage of mean daily time spent in different 24 h activities including sleep, sedentary time, LPA, and MVPA is presented in ***Figure 5.2.***

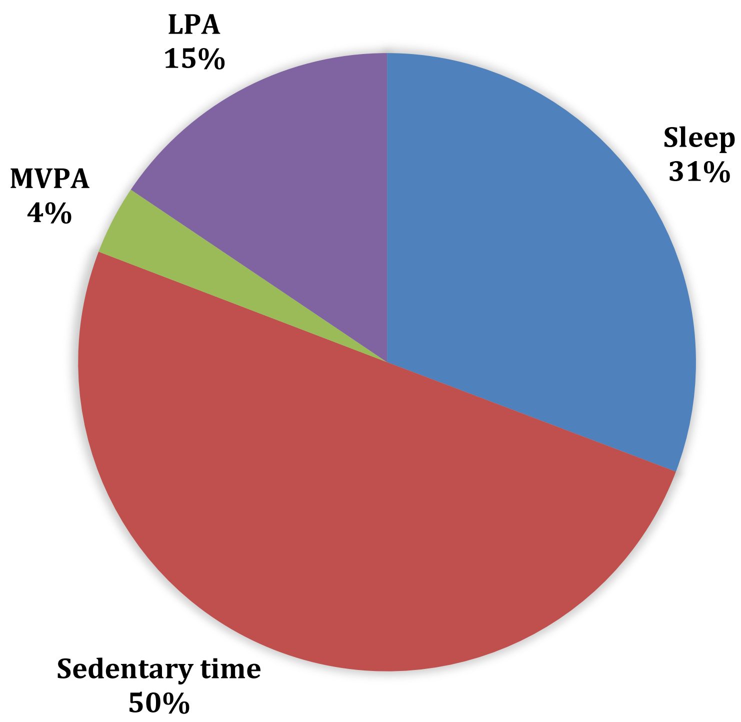

Figure 5.2: Total percentage of mean daily time spent in sedentary time, sleep, MVPA, and LPA

5.4 Differences in sleep, sedentary time, light and moderate-to-vigorous physical activity across categories of BMI

Mean time spent engaging in sedentary time and light physical activity across the different categories of BMI are presented in ***Table 5.3.*** No meaningful differences were observed between BMI categories for mean time spent sedentary and total time (wear-time plus self-reported non-wear-time). Healthy weight participants, on average, slept for 24 minutes more per day than overweight or obese participants. However, overweight and obese participants on average accumulated 36 min and 30 min more LPA, respectively, compared to normal weight participants. Healthy weight participants accumulated 3.5 minutes more MVPA than overweight participants, and 18.5 more minutes than obese participants.

Table 5.3: Comparisons between body mass index and time spend in sleep duration, sedentary time, LPA and MVPA

Measure	**BMI**		
	Healthy	Overweight	Obese
24 h activity[1]			
Sleep, hours[2]	7.4 (1.5)	7.0 (1.3)	7.0 (0.9)
Sedentary time, hours[3]	11.5 (1.7)	11.5 (2.1)	11.5 (1.9)
LPA, hours[3]	3.4 (1.0)	4.0 (1.4)	3.9 (1.2)
MVPA, min[3]	51.8 (33.7)	48.3 (33.0)	33.3 (18.8)
Total recorded time[1]	22.4 (1.8)	22.7 (2.0)	22.2 (2.1)

[1] *Mean time (SD).* **2** *n=133.* **3** *n=134*

Abbreviations: BMI = body mass index, LPA = light physical activity, MVPA = moderate-vigorous physical activity.

5.5 Proportions meeting sleep and physical activity guidelines

Comparisons between BMI and percentage of participants meeting the recommended guidelines for sleep and moderate-to-vigorous physical activity are presented in ***Table 5.4.*** There are notable differences between the BMI category and prevalence of those meeting either the sleep guidelines, MVPA guidelines, or both. Compared to the healthy BMI category, 11.7% and 18.2% less people met the sleep guidelines in the overweight and obese category, respectively. Additionally, a further 5.8% and 20.9% less people met the MVPA guidelines in both categories compared to the healthy category.

Table 5.4: Comparisons between body mass index (BMI) and the percentage of participants meeting the sleep and MVPA guidelines

Prevalence (%) of those meeting guidelines	**BMI**			**Overall**
	Healthy	Overweight	Obese	
24 h activity				
Sleep duration[1]	27.3%	15.6%	9.1%	22.9%
MVPA[2]	30.0%	24.2%	9.1%	26.9%
Meeting both guidelines[1]	13.6%	6.3%	0%	9.2%

[1] *n=131.* [2] *n=134*

Abbreviations: BMI = body mass index, h = hours, MVPA = moderate-to-vigorous physical activity

6 Discussion

Investigations about physical activity among adolescent females in New Zealand (NZ) are limited, and research assessing 24 h activities is non-existent. This study aimed to describe the 24 h activity patterns including sleep, sedentary behaviour and physical activity, of a nationwide sample of adolescent females aged 15-18 y, in NZ. There is accumulating evidence indicating the combination of adequate sleep (8-10 h per day), limited sedentary time, and sufficient moderate-to-vigorous physical activity (MVPA) (>60 min/day, including bone-strengthening activities 3+ days per week), has various favourable health benefits for adolescents (Poitras et al., 2016; Tremblay et al., 2016).

The present study demonstrated that on average, female adolescents were participating in 49.1 minutes of MVPA per day, which is below the recommended guidelines (>60 minutes per day). In fact, only 26.9% met the physical activity guidelines. When considering the four aspects of 24 h activity, participants spent half their time sedentary, one-third sleeping, 15% in LPA, and only 4% in MVPA. A mere 22.9% of participants met the sleep guidelines of 8-10 h per night. Interestingly, those in the healthy body mass index (BMI) category were more likely to meet the physical activity guidelines (30%) and sleep guidelines (27.3%), compared to overweight (24.2% and 15.6%) and obese individuals (9.1% and 9.1%), respectively.

6.1 MVPA and adherence to the physical activity guidelines

At present, there is limited research on physical activity levels in NZ adolescent females. Data is either self-reported data from the Ministry of Health (Ministry of Health, 2019), was an unpublished governmental report with limited methodology from a decade ago (Maddison et al., 2010a), or used younger adolescents (12-14 y) from Otago only (Kek et al., 2019). Additionally, all three studies assessed physical activity in isolation only, not in relation with other 24 h activity.

Kek et al. (2019) and Maddison et al. (2010a) used Actigraph accelerometers to gage physical activity, and reported average time spent in MVPA was 45.8 min/day and 55.8 min/day, respectively. Furthermore, females in the Maddison et al. (2010b) study accumulated only 36 min/day. In comparison with 49.1 min of MVPA accumulated in the present study, this may indicate that female adolescents have increased their MVPA in the last decade. However, differences in the representativeness of the sample populations including age, ethnicity and deprivation does limit more definitive conclusions. In terms of prevalence, Ministry of Health (2019), Maddison et al. (2010b), and Kek et al. (2019) found 40.6%, 32.3%, and 39.2% of all participants, and 37.3%, 33%, and 36% of females met the physical activity guidelines, respectively. In the present study, time spent in MVPA was higher (49.1 min/day); however, fewer participants met the physical activity guidelines (26.9%); indicating there may have been a change in the distribution of physical activity across the participants between Maddison et al. (2010b) and the present study.

To date, the limited data investigating physical activity levels of adolescent females has either been self-reported (Ministry of Health, 2019), from unpublished results with limited methodology available (Maddison et al., 2010b), or from a single site (Kek et al., 2019), making comparisons between the present study difficult. However, based on results from the current study and others (Kek et al., 2019; Maddison et al., 2010b; Ministry of Health, 2019), it appears female adolescents are doing between 36 to 50 minutes of MVPA per day, and approximately 27% to 38% of participants are meeting the physical activity guidelines. It seems physical inactivity is problematic in NZ adolescent females, who, as a population, are likely to be missing out of the health benefits associated with being physically active.

Guthold et al. (2019) conducted a pooled analysis of cross-sectional survey data reporting global trends in self-reported physical inactivity among 1.6 million adolescents across 146 countries. Overall, 81.0% of adolescents (11-17 y) did not meet the physical activity guidelines, and 84.7% of girls did not meet the guidelines compared to males (77.6%) (Guthold et al., 2019). Additionally, objectively measured physical activity data from the United States, Canada, Germany and nine other European countries reported female adolescents spent 19.6 min, 39 min, 55 min and 49 min per day in MVPA, respectively; and 5.4%, 2%, 1% and 27.5% met the physical activity guidelines. Self-reported data from Australia and South Africa indicated that 7.2% and 0% of adolescent females met the physical activity guidelines. The current study reported 26.9% of female adolescents met the physical activity guidelines, highlighting 73.1% are currently inactive. Despite differences in methodology, results from the present study indicate NZ adolescent females are accumulating MVPA in similar to greater amounts than their international counterparts. Furthermore, NZ female adolescents appear to have higher adherence to the physical activity guidelines in comparison with other countries.

6.2 24 h activity

There are minimal similarly designed studies that also measure sleep, sedentary behaviour, LPA, and MVPA using accelerometers. Carson, Tremblay, Chaput, and Chastin (2016) found that participants (6-17 y) spent 38% of time sedentary, 40% sleeping, and the remainder in LPA (18%) and MVPA (4%). In comparison, the present study found participants spent 50% of time sedentary, 31% sleeping, 15% in LPA, and 4% in MVPA. Differences, especially in sedentary time and sleep are most likely attributable to the inclusion of 6 to 14 y olds, as movement behaviours often decrease as a function of age (Tremblay et al., 2016). In adults, and using accelerometers, Chastin, Palarea-Albaladejo, Dontje, and Skelton (2015a) found time was mainly spent sedentary (40%), followed by sleep (28%), LPA (29%), and MVPA (3%). Participants in the current study fall between the ages of these two studies. Differences in sleep and MVPA between the current study and the Carson et al. (2016) and Chastin, Palarea-Albaladejo, Dontje, and Skelton (2015b) study are probably what would be expected in this age group. The current study and Chastin et al. (2015b) use the same cut-off points to identify sedentary time and intensities of activity. Therefore, the much larger time spent sedentary in the current study is likely to be a true, and somewhat concerning difference. It is possible that the sedentary behaviour was noticeably higher in our study because adolescents contribute less to the running of a household than adults and have homework to complete that requires them to be sedentary.

6.3 Differences in sleep, sedentary time, LPA and MVPA across categories of BMI

Individual components of the 24 h day (e.g. physical activity) have been assessed across different BMI categories. However, to our knowledge, no studies have reported on the entire 24 h activity patterns across different BMI categories. The present study shows those who are in the healthy BMI category slept for longer, spent more time in MVPA, and were more likely to meet the sleep and MVPA guidelines compared to their overweight and obese counterparts. However, the longer time spent in MVPA and sleep was lost in LPA, as healthy weight participants accumulated 36 min and 30 min less than overweight and obese participants. Cross-sectional analysis does not allow for inferences for causality. However, future research should investigate the causality of the association. Regardless of the direction of the association, targeting sleep and MVPA in overweight and obese participants could lead to better health outcomes.

6.4 Strengths and limitations

The following limitations need to be considered when interpreting the results. Firstly, accelerometers positioned on the hip do not accurately capture intensity of some exercises (e.g. cycling, upper body exercises, and swimming), meaning that activity could be underreported in some individuals. However, to minimise underestimating physical activity, our inclusion of a wear-time diary provided participants the opportunity to record physical activity done without the accelerometer.

The methodology for accelerometer use is hugely variable as researchers can choose between the type of device, body positioning, epoch length, bouts of movement, data inclusion/exclusion, and cut-off points used. Currently, there is no definitive consensus on the most accurate methodology, including the cut-off points applied to distinguish SB, LPA, and MVPA. In the present study, we used cut-off points from (Freedson et al., 1998) as our participants (aged 15-18 y) were most likely closer in size to the population of young adults in the study. Additionally, the use of an algorithm (Sadeh et al., 1994) to identify sleep from the accelerometer data, while validated, is likely in some participants to over or underestimate sleep, which as a consequence is also likely to impact the estimate of sedentary time.

The accelerometers were unable to differentiate between different sedentary behaviours (e.g. screen-time vs non-screen time); therefore, the prevalence of those meeting the screen-time recommendation is unable to be calculated. Hip-worn Actigraph accelerometers also lack the ability to distinguish posture. For example, a still standing person may be classified as sedentary, even though sedentary behaviour is defined as being in a seated position (Tremblay et al., 2017). However, accelerometry is considered less biased and more robust than self-reports and is clearly a superior tool for the measurement of 24 h activity.

Our population sample was 15-18 y old females. The current guidelines recommend children (5-12 y) and adolescents (12-17 y) attain at least 60 min/day of MVPA, compared to adult (18-65 y) guidelines of at least 150 min/week of MVPA. For study convenience and due to a small percentage of 18 y olds (n=7), we chose to compare the whole sample to the youth guidelines. However, if the 7 participants did at least 30 min per day of MVPA, it would increase the prevalence of those meeting the physical activity guidelines from 26.9% to 32.1%.

The present study had several strengths. Firstly, this study included an analytical approach to measuring 24 h movement data as a whole. The combination of accelerometry and self-report diaries to measure all 24 h movement behaviour enabled researchers to capture habitual physical activity, as well as duration of sleep and sedentary behaviour. Furthermore, the accelerometer used in the present study is one of the most commonly used research devices for assessment of physical activity, and more recently 24 h behaviours, thus enabling comparisons with any existing or future studies. Participants included a wide-spread sample of female adolescents from 8 locations across New Zealand, providing a more heterogeneous sample than single-site studies. Lastly, data collection was taken in the comfort of each participants school, therefore minimising environmental confounders.

6.5 Recommendations and considerations for future research

The current study has identified several requirements that should be considered for future research. Firstly, the present study was unable to differentiate between sedentary pursuits (e.g. screen-time vs non-screen time), meaning we were unable to compare sedentary behaviour adherence to the screen-time guidelines (<2 h per day). Screen time has been more strongly linked with poorer health outcomes (Ekelund et al., 2016); thus, it is essential to distinguish this behaviour from other sedentary behaviours. Reporting adherence to the screen-time guidelines, MVPA guidelines and sleep guidelines will enable researchers to assess compliance to all 24 h movement guidelines in total. Future studies could include a screen time log in the self-reported diary.

Recommendation: Future research should distinguish between screen-time sedentary behaviour and non-screen sedentary behaviour.

This study reported comparisons between BMI categories and time spent in 24 h activities (e.g. physical activity). Compared to those in the healthy BMI category, overweight and obese participants slept less and obtained less MVPA min per day. This warrants further investigation and more research is needed to distinguish the causality of the association.

Recommendation: Future research should distinguish between the causality of the association between BMI category and time spent in each behaviour.

It is apparent that female adolescents are engaging in low levels of physical activity and spending over half their time sedentary. Clearly, interventions promoting physical activity among youth is not working or having meniscal effects. To develop effective interventions, the target population and their behaviours must be understood. Utilising future 24 h activity research similar to the present study will help the planning and development of more targeted and hopefully effective interventions.

Recommendation: Plan and develop public health interventions targeting 24 h activity.

6.6 Conclusion

To our knowledge, this is the first study to measure 24 h movement activity in NZ adolescent females. The present study highlights that adolescent females aged 15-18 y in NZ are spending approximately half their time sedentary, one-third sleeping, and 15% and 4% in LPA and MVPA, respectively. On average, participants spent 49.1 min/day in MVPA, and only a shocking one in four participants met either the sleep or physical activity guidelines, and only one in ten met both. Persisting with these inactive behavioural choices among adolescents could have detrimental effects on the health of this population with potentially an increased development of chronic disease. Understanding the prevalence of adhering to 24 h guidelines rather than individual guidelines will be crucial to the planning and development of public health policies and interventions.

7 Application to dietetic practice

7.1 Relevance of research to dietetic practice

Dietitians commonly work to promote health and well-being using a holistic health approach for individuals and communities. Aside from nutrition, several other factors need to be considered, including sleep, physical activity, income, resources etc. These factors must also be considered for the development of public health policies and interventions. In order to provide effective and successful care, and targeted interventions, practitioners and researchers must first understand the specific group they are working with.

The present study highlights the importance of 24 h activity (sleep, sedentary behaviour, and physical activity) in combination, plus gives insight into current 24 h activity levels of adolescent females in New Zealand. The findings indicate that female adolescents in New Zealand are spending half their time sedentary, and on average, only obtaining 49.1 minutes of moderate-to-vigorous physical activity each day. Approximately, one-quarter of participants meet the sleep guidelines (8-10 h/day) or the physical activity guidelines (>60 min/day), and approximately one in ten are meeting both.

Research conclusions are applicable to my dietetic practice. Firstly, understanding how each component of 24 h activity affects another, made me realise this is similar with nutrition. Numerous factors are affecting a person's nutrition; therefore, an in-depth assessment including questions on physical activity levels, sleep, type of job, etc., can highlight these factors. I could then assist the patient by using a multidisciplinary team (MDT) approach, or through recommendations or referrals. This will improve my patient-centred care and thus, the patient's overall wellbeing. Additionally, the ability to review and evaluate literature critically will be instrumental in my future when providing evidence-based information and for life-long learning.

7.2 What this research experience has meant to me

For me, the most relevant learning from this research project was the importance of communication and teamwork. In comparison with those in a pair, a four-person group required more planning and distribution of individual roles. I was initially hesitant and assumed this would be a disadvantage as the likelihood of mistakes or doubling up on work was higher. However, to combat this, we were proactive at developing effective communication strategies, including making a group discussion page, developing daily planning sheets, and producing a google document accessible by each person. The effectiveness of these strategies was evident when we were asked to assist with 24-hour diet recalls in a different location. We were able to distribute tasks to each team member successfully and complete 35 additional diet recalls by phone call.

This experience emphasised the importance of communication to ensure the task at hand is completed correctly. I also learnt that distributing tasks based on each team members strength tended to deliver the best results. The skills learnt are transferable into my future career when working in a team of dietitians. I will endeavour to use and promote effective communication, planning techniques, and teamwork skills. The above skills will also help improve my competency as a dietitian.

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9 Appendices

Appendix A: Ethics proposal and approval letter

H19/004

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

Academic Services
Manager, Academic Committees, Mr Gary Witte

4 February 2019

Dr J Haszard
Department of Human Nutrition
Division of Sciences

Dear Dr Haszard,

I am writing to let you know that, at its recent meeting, the Ethics Committee considered your proposal entitled "**SuNDiAL Project 2019: Survey of Nutrition Dietary Assessment and Lifestyle Phase 1: Adolescent Females**".

As a result of that consideration, the current status of your proposal is:- **Approved**

For your future reference, the Ethics Committee's reference code for this project is:- **H19/004**.

The comments and views expressed by the Ethics Committee concerning your proposal are as follows:-

While approving the application, the Committee would be grateful if you would respond to the following:

Information Sheet

A typing error was noted on the Information Sheet, under the heading *"Is there any risk of discomfort or harm from participation?"*, line 3, "some" should read "someone".

Consent Form

Please amend the Consent Form to include an option for participants to indicate whether they would prefer for their blood samples to be disposed of using standard methods or with a Karakia.

Please provide the Committee with copies of the updated documents, if changes have been necessary.

The standard conditions of approval for all human research projects reviewed and approved by the Committee are the following:

Conduct the research project strictly in accordance with the research proposal submitted and granted ethics approval, including any amendments required to be made to the proposal by the Human Research Ethics Committee.

Inform the Human Research Ethics Committee immediately of anything which may warrant review of ethics approval of the research project, including: serious or unexpected adverse effects on participants; unforeseen events that might affect continued ethical acceptability of the project; and a written report about these matters must be submitted to the Academic Committees Office by no later than the next working day after recognition of an adverse occurrence/event. Please note that in cases of adverse events an incident report should also be made to the Health and Safety Office:

http://www.otago.ac.nz/healthandsafety/index.html

Advise the Committee in writing as soon as practicable if the research project is discontinued.

Make no change to the project as approved in its entirety by the Committee, including any wording in any document approved as part of the project, without prior written approval of the Committee for any change. If you are applying for an amendment to your approved research, please email your request to the Academic Committees Office:

gary.witte@otago.ac.nz

jo.farrondediaz@otago.ac.nz

Approval is for up to three years from the date of this letter. If this project has not been completed within three years from the date of this letter, re-approval or an extension of approval must be requested. If the nature, consent, location, procedures or personnel of your approved application change, please advise me in writing.

The Human Ethics Committee (Health) asks for a Final Report to be provided upon completion of the study. The Final Report template can be found on the Human Ethics Web Page http://www.otago.ac.nz/council/committees/committees/HumanEthicsCommittees.html

Yours sincerely,

Mr Gary Witte
Manager, Academic Committees
Tel: 479 8256
Email: gary.witte@otago.ac.nz

c.c. Assoc. Prof. L Houghton   Department of Human Nutrition

Appendix B: Protocol Manual

SuNDiAL Project: Survey of Nutrition Dietary Assessment and Lifestyle

2019 & 2020: Adolescent Females

PROTOCOL MANUAL

1

Updated June 2019

Funding Agencies: Department of Human Nutrition
Lottery Health Research Grant

Study Investigators

Principal Investigator:	Dr Jill Haszard[1] Ph. +64 3 479 5683 Email: jill.haszard@otago.ac.nz
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in a modern vegetarian diet that is markedly different from that consumed prior to the 1990s. Therefore, it is imperative to examine the modern vegetarian-eating pattern to determine whether it continues to offer the health benefits it once did.

Even when a vegetarian is eating a diet that offers cardio-protective benefits, ensuring the nutritional adequacy of a meatless diet requires care. The dietary intakes of vegetarians, and particularly vegans (those who do not consume meat, poultry, fish, dairy or eggs) may be inadequate for some nutrients including iron, zinc, calcium, vitamin B_{12}, and vitamin D, which could negatively impact their long-term health. Indeed, the bone mineral content of vegetarians tends to be ~4% lower than omnivores [3], potentially putting them at higher risk of fracture and the development of osteoporosis. In addition, the poorer absorption of iron from a vegetarian diet increases the risk of iron deficiency [7]. However, it is unknown how the modern vegetarian diet may exacerbate or protect against the risk of nutrient deficiencies in the current food environment.

Despite the apparent increasing popularity of vegetarian diets we are currently reliant on commercial market research to give an indication of the rates of vegetarianism on New Zealand [8]. Surveys conducted in 2011 and 2015 indicate that rates of vegetarianism in New Zealanders in those aged 14 to 24 years exhibited the largest increase of any age group – from 8.6% to 13.3% [8]. Adolescent females may be at risk of poor iron status even when following a diet that includes iron-rich meat. Furthermore, adolescents represent the future of this country, and may be an appropriate target for instigating the dietary shifts recommended by the EAT-Lancet Commission. These factors together make adolescent females an important population in which to begin an assessment of vegetarianism in New Zealand, examining the health correlates of a modern vegetarian diet, while also assessing the possible risks of nutrient inadequacy and deficiency.

3. Aim of Study

To compare the dietary intakes and habits, nutritional status, health status, motivations, attitudes, and lifestyles of vegetarian and non-vegetarian adolescent females in New Zealand.

4. Objectives

To describe the dietary intake of macronutrients, sugars, fibre, and key micronutrients (iron, zinc, B12, folate, iodine, fluoride, magnesium, riboflavin, and calcium) in a sample of adolescent females in New Zealand, and to make comparisons between vegetarians and non-vegetarians

To describe the biochemical micronutrient status of key micronutrients (iron, zinc, vitamins A, B6, B12, folate, selenium, and thiamin) in a sample of adolescent females in New Zealand, and to make comparisons between vegetarians and non-vegetarians.

To describe the 24-hour activity patterns (sleep, sedentary behavior and physical activity) in a sample of adolescent females in New Zealand, and to make comparisons between vegetarians and non-vegetarians

To determine the attitudes and motivations towards food choice/dietary patterns (e.g., the environment, animal welfare, health) in a sample of adolescent females in New Zealand, and to make comparisons between vegetarians and non-vegetarians

To describe dietary habits in a sample of adolescent females in New Zealand and to make comparisons between vegetarians and non-vegetarians

To describe the weight loss intentions and methods of adolescent females in New Zealand and to make comparisons between vegetarians and non-vegetarians

5. Hypothesis

We hypothesize that vegetarian adolescent females will differ from non-vegetarian females in terms of nutrient intake, micronutrient status, attitudes and motivations, and other lifestyle factors.

6. Study Design

Cross-sectional survey

7. Study Setting/ Location

A multi-centered study including at least 14 high schools across New Zealand, along with targeted recruitment of vegetarians. The localities in which data will be collected are determined by where data collectors (MDiet students) will be based in 2019 & 2020. In 2019 these locations are:

- Dunedin
- Wellington
- Christchurch
- New Plymouth

- Nelson
- Whangarei
- Tauranga
- Wanaka

After 6 months of data collection when 145 participants had completed the study, a decision was made to specifically target recruitment of vegetarians as only nine had enrolled in the study. Therefore, in Dunedin, adolescent females who identify as vegetarian, but are not enrolled in a participating school will also be able to participate in the study.

8. Study Population

At least 300 female high school students between the ages of 15 to 18 years from across New Zealand.

9. Eligibility Criteria

9a. Inclusion criteria

Individuals who self-identify as female and are between 15 and 18 years of age, who are enrolled in one of the recruited high schools, or who identify as vegetarian living in Dunedin will take place, and who speak and understand English and are able to complete the required online questionnaires are eligible to participate..

9b. Exclusion criteria

Participants will be asked not to participate in this study if they know that they are pregnant.

10. Study Outcomes

10a. Primary Outcomes

Iron intake and biochemical iron status

10b. Secondary Outcome(s)

Intake and biochemical status of other nutrients
Attitudes and beliefs around food choice, including dietarian identity, food choice motivations.
Dietary habits

BMI z-score
24-hour activity patterns (time spent in sedentary behavior, physical activity and sleep)
Weight loss intentions & methods

11. Study Procedures

11a. Recruitment of participants

There are two methods of recruitment: school-based recruitment and targeted recruitment. The school-based recruitment aims to recruit female adolescents with a broad range of dietary patterns, whereas the targeted recruitment aims to recruit female adolescents who identify as vegetarian.

School-based recruitment

First schools will be recruited and then students at that school will be invited to participate. High schools in the areas in which data collectors are based will be invited to participate. Initially an email invitation will be sent to schools with the largest female roll, from a range of deciles. The PIs (JH and MP) and/or the SuNDiAL coordinator (Tessa Scott) will initiate contact via email from November 2018. Schools that do not respond to the email within two weeks will be sent a second email, and will receive a follow-up phone call. If email and phone contact does not result in the targeted number of schools enrolling in the study (one school per pair of data collectors) schools in the data collection area may be recruited via word of mouth. Interested schools will be phoned to provide information about the dates and times that suit them to have the research teams conducting data collection at the school, as well as information about the facilities and space that they can make available to the research team.

Master of Dietetic students (the data collectors) will visit participating schools early in the term to initiate recruitment of students within the school. This visit may include a presentation to school or year group assemblies, and may also involve providing the school with electronic and/or print information that can be circulated with school newsletters etc.

School students who are interested in participanting will be given the opportunity to provide their name, age, and email address after the in-school presentation, where information sheets will be available. Alternatively, school students who are will also be able to visit the study website (www.otago.ac.nz/sundial) where they will be able to read more information about the study, watch a short video about what is involved in participating, and read the information sheet. Individuals interested in participating can then provide their name, age, email address, and high school to the website. An ID number will be assigned to the participant at this point and the SuNDiAL coordinator will email the participant a link to a REDCap questionnaire, where they will complete online consent, and answer a series of questions about demographics and health. Potential participants are free at any time to contact investigators via phone or email to ask questions about participating in the study. Where a participant is under 16 years of age, they will be asked to provide the email address of a parent/guardian, who will then be contacted via email, and asked to provide online consent for their daughter to participate before the link to the study is sent to the participant.

Targeted recruitment

Advertising for females aged 15 – 18 who identify as vegetarian will take place in Dunedin. Advertising will be in local papers and social media. Females who are interested in participating will be directed to the study website (www.otago.ac.nz/sundial), where they can view a video about the study, read the information sheet, and if they wish to participate they will provide their contact details (name and email address) so that a link to the online consent and enrolment forms can be sent to them.

11b. Study procedure

Once participants have completed online consent, and answered the initial demographic, vegetarianism, and health questions they can continue on to complete the rest of the online questionnaires or return to complete them later. These additional questionnaires assess dietary habits, and attitudes and motivations to food choice, as well as weight-loss intentions and methods. These are administered on the web application REDCap and are completed in their own time.

Participants will be contacted by data collectors (either by phone or email) to be scheduled to attend a visit with study investigators at school during school time (if they are part of the school-based recruitment group), or at the clinic after school (if they are part of the targeted recruitment group). During this visit participants will carry out a 24-hour dietary recall with one of the Master of Dietetics students. Height, weight and ulna length will be measured in duplicate. It is expected that this part of the data collection visit will take approximately 60 minutes to complete.

Individuals who consent to wear an accelerometer will be fitted with an Actigraph GT3x+ accelerometer to be worn on an elasticated belt over their right hip continuously for 24 hours a day for seven days. Participants wearing an accelerometer will also be asked to complete a sleep and wear time diary over the time which the accelerometer is worn, which will involve recording the times they went to bed and to sleep each night, and to record any time for which the accelerometer was removed for more than five minutes. Actigraphs and sleep & wear time diaries will be collected eight days after the initial visit by a data collector.

A second 24-hour dietary recall will be undertaken over the phone or by video-call. This will take place the following weekend to capture the variation in dietary intake between days, including weekend days. Completion of this second dietary recall should take participants approximately 30 min.

Participants who consent to providing a blood sample will have one collected by the trained phlebotomist/research nurse at an appointed time. Participants may also provide a urine sample (collection of biochemical samples may occur on a separate day to the 24 h recall depending on the availability of the phlebotomist).

11c. Measurement tools used

Demographics, vegetarianism, and health status

After the participant has given consent (and a parent or guardian has given consent if they are 15 years of age) then they will continue on to an online questionnaire assessing demographics, vegetarianism, and health status, such as whether they are diabetic and questions about their menstruation patterns (to estimate iron requirements). This is administered in REDCap.

Dietary habits, weight-loss intentions & methods, attitudes and motivations for food choice

Dietary habits, and attitudes and motivations for food choice will be assessed via questionnaires administered in REDCap. These online questionnaires will be available for the participant to complete in their own time after they have consented. The majority of these questionnaires are based on previously validated questionnaires [9-14] where, if necessary, modifications (such as changing of country specific jargon) have been made to make them suitable for New Zealand female adolescents.

Dietary intake

Estimates of dietary intake will be calculated for each participant through the completion of two 24 recalls. During each 24 recall participants will be asked to recall everything they eat from midnight to midnight the previous day. Participants will be prompted to recall details such as brands of food items and cooking methods. Participants will be asked to estimate quantities using household measures, food models, and photographs of different portion sizes.

The recalled foods and portion sizes will then be entered into FoodWorks 9 (Xyris Software Australia Pty Ltd) by the MDiet students to calculate the energy, macronutrients and micronutrients contained in the recalled diet. FoodWorks uses the most up-to-date and comprehensive food composition tables for New Zealand (FOODfiles 2018 (The New Zealand Institute for Plant & Food Research Limited)) which was enhanced by the inclusion of ANS0809 recipe calculated foods. The administration of a second 24-hour diet recall will allow for an estimation of 'usual intake', by using the MSM programme to adjust for the within-person variation in intakes [15].

Biological specimens

A total of 10 ml of blood will be collected into two separate tubes (one 4ml and one 6 ml tube) by a trained phlebotomist. The 4 ml tube will be used to by a local laboratory affiliated with Southern Community Laboratories to perform a complete blood count, and measure Vitamin B12. The 6 ml blood sample will be centrifuged within four hours of collection, by the local laboratory, before being aliquoted into 4 storage tubes and transported on ice to the Department of Human Nutrition at the University of Otago in Dunedin. Samples will be stored at -80°C. Once all blood samples have been collected, one aliquot from each participant will be sent to the VitMin Lab in Germany for analysis of ferritin, soluble transferrin receptor, retinol binding protein, c-reactive protein and alpha-glycoprotein. The remaining blood samples be retained in the Department of Human Nutrition, where they will be analyzed for plasma selenium and plasma zinc, thiamin, plasma folate, B6, Leptin, and IL-6.

The urine sample provided by the participant will be transferred into a storage container and then transported on ice to the Department of Human Nutrition at the University of Otago in Dunedin by the local laboratory who is performing the processing of blood samples. Samples will be stored at -20°C until analysis of iodine concentrations.

The University of Otago, Department of Human Nutrition Micronutrient Laboratory will run the analyses for the biochemistry samples.

24-hour activity

24-hour activity patterns will be assessed using data collected using the Actigraph GT3x+. Data from each accelerometer will be downloaded using Actilife software and deposited electronically onto the password protected SuNDiAL folder on the University's shared server. Accelerometer data will then be transferred into Stata (StataCorp. 2017. *Stata Statistical Software: Release 15*. College Station, TX: StataCorp LLC) where it will be cleaned, wear time and sleep time will be entered, and age appropriate cutoffs used to identify time spent in sleep, sedentary behavior, as well as light, moderate and vigorous physical activity for each 24-hour period.

Anthropometry

All data collectors will be trained to measure height, weight, and ulna length according to study protocols, which are based on published protocols [16, 17]. Height will be measured in duplicate using stadiometers (Seca 213; and Wedderburn), weight will be measured in duplicate using scales (one of Medisana PS420; Salter 9037 BK3R; Seca Alpha 770; or Soehnle Style Sense Comfort 400) that have been calibrated by the research team. Ulna length will be measured in duplicate on the non-dominant side.

11d. Data monitoring and Quality Control

No formal data monitoring will take place.

Data collection will be the responsibility of investigators under the supervision and direction of the PIs. The use of REDCap will minimize the need for extensive data entry and cleaning, although checks of each variable will be undertaken before statistical analysis takes place.

Quality control will be ensured by developing standard operating procedures for all data collection, including:

- Anthropometry (height, weight, ulna length);
- 24-hour dietary recall;
- Collection of blood sample and urine samples;
- Fitting the accelerometers;
- Data entry into FoodWorks

To further ensure the quality of the data collected, all data collectors (MDiet students) will have completed a six-week research methods paper in the previous year, led by the PIs. This focuses on preparing them for this research project. A further two weeks of intensive training in data collection procedures will occur prior to data collection. Any additional data collectors (MSc or PhD students) will undergo the same training.

The intensive training will be led by the PIs (Drs Jill Haszard and Meredith Peddie) with expertise brought in as needed (e.g., to teach about FoodWorks and food composition tables). This will cover obtaining informed consent, conducting research studies, dietary data collection and anthropometric measurements, handling biological samples, and fitting accelerometers.

During data collection, the students will receive ongoing support from the study investigators.

12. Statistical Considerations and Data Analysis

12a. Sample size and statistical power

A sample size of 300 high school students enrolled from 14 high schools gives 80% power to the α=0.05 level to detect a 0.5 standard deviation difference (a "moderate" difference) in continuous outcome variables between vegetarians and non-vegetarians, assuming a prevalence of vegetarianism of 20% and a design effect (for school clusters) of 1.5.

12b. Statistical methods

Statistical analyses will be carried out using Stata (StataCorp. 2017. *Stata Statistical Software: Release 15*. College Station, TX: StataCorp LLC). School clusters will be accounted for in all analyses using appropriate methodology (for example, with the survey command, a sandwich estimator, or as a random effect). Dietary intake estimates will be adjusted for 'usual intake' using the Multiple Source Method (MSM) [15]. Estimates of prevalence and means will be reported with 95% confidence intervals. A binary variable for vegetarianism will be created and comparisons between vegetarians and non-vegetarians will be carried out using appropriate regression models. All data management and statistical analysis will be overseen by the study biostatistician, Dr Jill Haszard (PI).

13. Ethical Considerations

13a. Ethical Standards

This study is conducted in full conformity with the current revision of the Declaration of Helsinki, or with the International Conference for Harmonization Good Clinical Practice (ICH-GCP) regulations and guidelines, whichever affords the greater protection to the participant, as well as the laws and regulations of New Zealand. All dietetic students are trained under the Code of Health and Disability Services Consumers' Rights 1996. They adhere to the New Zealand Dietitians' Board Code of Ethics.

13b. Quality Assurance

This research will be conducted by researchers who are highly skilled in the technical aspects of this research study, in particular dietary and nutritional assessment.

13c. Risks/safety considerations

Participant Burden: To reduce the respondent burden for the participant, questionnaires will be completed online in their own time. For those recruited through schools, completing the second dietary assessment questionnaire outside of school time will also minimize any further disruption to the participant's school day.

Blood sampling: There is a risk of discomfort, pain and bruising from the blood test. Participants will be informed of these risks, and an experienced nurse or phlebotomist will collect the blood samples and ensure strict aseptic technique is followed during blood collection to minimize any risk of infection.

The data collectors will be briefed on health and safety policies and procedures at their respective schools and will comply with these for the duration of the study. Examples of such policy and procedure will include, but not be limited to:

- Emergency procedures
- Biological sample handling

MDiet students have been vaccinated for Hepatitis B as a requirement for admission into the Dietetics program.

Informed Consent Process

Information about the study will be provided to potential participants at either an in-school presentation; and/or through the website, where an informative video about the study can be viewed and a detailed information sheet will be available. The information sheet will also be provided at the school presentation. Participants will be encouraged to discuss this with their family/whanau. Participants can enter their name, age, email address, and school on the website (or on a sign-up sheet at the school presentation) if they are interested in participating. At this point an ID number will be assigned to them and an email sent with a link to the consent form. If at any time potential participants have questions about the study they can contact the investigators via email or phone. Once participants have had all their questions answered they can provide consent by completing the consent form electronically. The participant (or their legally authorized representative) can withdraw consent at any time throughout the course of the study. Consent information will be stored electronically in REDCap.

Participant Confidentiality

Participant confidentiality is strictly held in trust by the investigators. This confidentiality is extended to cover testing of biological samples and to the clinical information relating to participants.

Upon enrolment, participants will be assigned a unique identifying code, this is done automatically by REDCap. To preserve confidentiality, during data collection all data will be recorded against this ID number. The information linking the code to the participant's identity will be stored in a separate password protected file that only the PIs (MP and JH) and the SuNDiAL coordinator will have access to.

Responses to online questionnaires will be electronically linked to study ID numbers, as will accelerometer data. Study ID number will also be written on all biological sample tubes and the recording sheets for anthropometry measurements and 24 h recalls.

Follow-up

Once the data from the study have been analysed, the participants will be provided with an overall summary of the results. Participants are also free to request a copy of their individual data. All participants who provide a blood sample will also be provided with their biochemical haemoglobin, mean cell volume, mean cell haemogolbin, platelets, white blood cells, folate and B12 status, with a note about how to interpret these values. If investigators identify a risk of anaemia in any participant they will be advised to see their general practitioner to speak to them about these results.

Participating schools will also be provided with a summary of both the overall results as well as a summary of selected results obtained from their school (e.g. percentage of girls consuming breakfast, average number of servings of fruits and vegetables etc.)

If student investigators are concerned about an aspect of the nutritional or mental health of a study participant, they may suggest that the participant contact their school counsellor and/or nurse.

Data Management

Data will be collected as per Standard Operating Procedures and cleaned as per standard data entry procedures. Data quality checks will be run on all entered data to check for accuracy, consistency and completeness. The results database will be stored on the investigators' computers, all of which are password protected. A backup copy may also be stored on the University's shared server space, but only the PIs (JH and MP) will have the password that will enable access to the data stored on the server.

Information linking participant identity to their ID number will be stored in a separate password protected file that only the PIs (JH and MP) will have access to. The only reason this information will be accessed once the study is completed is if the participant requests their individual results. This file will be destroyed once all participants have been given the opportunity to request individual information. The de-identified information collected as part of this research will be retained for at least 10 years in secure storage.

14. Outcomes and Significance

As a result of the last national nutrition survey, conducted in 2008/09, vegetarianism has been identified as a priority area of nutritional concern by the Ministry of Health. This study will provide a meaningful investigation into the nutritional biochemical status and well-being of New Zealand female adolescents, who, as a population group are likely to have one of the highest rates of vegetarianism. We will be able to assess whether the 'modern' vegetarian diet consumed by adolescent females offers substantial benefits or risks over a non-vegetarian eating pattern. The collection of biochemical data, along with dietary intake and beliefs and motives for adopting a vegetarian lifestyle will strengthen the outputs and aid in the description of the health benefits associated with vegetarianism, but also the identification of 'at risk' individuals, to support up-to-date government and health agency guidelines for adolescent women.

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Appendix C: Accelerometer wear-time and Sleep Diary

Accelerometer Sleep and Wear Time Diary

PARTICIPANT ID: ____________________

Day One

Day of the Week ______________________ Participant ID: ____________________________

During the day I removed the accelerometer:

Removal time _________ back on: ___________ Reason __________________

Removal time _________ back on: ___________ Reason __________________

Removal time _________ back on: ___________ Reason __________________

Removal time _________ back on: ___________ Reason __________________

Removal time _________ back on: ___________ Reason __________________

Removal time _________ back on: ___________ Reason __________________

During the day I did the following activity that might not have been recorded e.g swimming, biking or resistance activities (weights):

Description of Activity ______________ Time began: _______________ Time ended: _______

Intensity of activity: Light* ▯ Moderate** ▯ Vigorous*** ▯

Description of Activity ______________ Time began: _______________ Time ended: _______

Intensity of activity: Light ▯ Moderate ▯ Vigorous ▯

Description of Activity ______________ Time began: _______________ Time ended: _______

Intensity of activity: Light ▯ Moderate ▯ Vigorous ▯

*Activities which do not markedly increase heart rate of breathing rate

** Activities that elevate heart rate and breathing, but during which you can hold a conversation

***Activities that involve considerable exertion, and during which you are breathing so hard you can talk

Day One

SLEEP LOG (to be recorded the next morning)

What time did you lie down in bed last night:		Record time
What time did you try to go to sleep? (turned off light/put down phone)		Record time
About how long do you think it took you to fall asleep?		Record minutes
What time did you wake up this morning?		Record time
What time did you get out of bed this morning?		Record time

Day Two

Day of the Week ______________________ Participant ID: ____________________________

During the day I removed the accelerometer:

Removal time _________ back on: __________ Reason _________________

Removal time _________ back on: __________ Reason _________________

Removal time _________ back on: __________ Reason _________________

Removal time _________ back on: __________ Reason _________________

Removal time _________ back on: __________ Reason _________________

Removal time _________ back on: __________ Reason _________________

During the day I did the following activity that might not have been recorded e.g swimming, biking or resistance activities (weights):

Description of Activity _____________ Time began: ______________ Time ended: _______

Intensity of activity: Light* ☐ Moderate** ☐ Vigorous*** ☐

Description of Activity _____________ Time began: ______________ Time ended: _______

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

Description of Activity _____________ Time began: ______________ Time ended: _______

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

*Activities which do not markedly increase heart rate of breathing rate

** Activities that elevate heart rate and breathing, but during which you can hold a conversation

***Activities that involve considerable exertion, and during which you are breathing so hard you can talk

Day Two

SLEEP LOG (to be recorded the next morning)

What time did you lie down in bed last night:		Record time
What time did you try to go to sleep? (turned off light/put down phone)		Record time
About how long do you think it took you to fall asleep?		Record minutes
What time did you wake up this morning?		Record time
What time did you get out of bed this morning?		Record time

Day Three

Day of the Week ______________ Participant ID: ______________

During the day I removed the accelerometer:

Removal time ________ back on: ________ Reason ______________

Removal time ________ back on: ________ Reason ______________

Removal time ________ back on: ________ Reason ______________

Removal time ________ back on: ________ Reason ______________

Removal time ________ back on: ________ Reason ______________

Removal time ________ back on: ________ Reason ______________

During the day I did the following activity that might not have been recorded e.g swimming, biking or resistance activities (weights):

Description of Activity ________ Time began: ________ Time ended: ________

Intensity of activity: Light* ▯ Moderate** ▯ Vigorous*** ▯

Description of Activity ________ Time began: ________ Time ended: ________

Intensity of activity: Light ▯ Moderate ▯ Vigorous ▯

Description of Activity ________ Time began: ________ Time ended: ________

Intensity of activity: Light ▯ Moderate ▯ Vigorous ▯

*Activities which do not markedly increase heart rate of breathing rate

** Activities that elevate heart rate and breathing, but during which you can hold a conversation

***Activities that involve considerable exertion, and during which you are breathing so hard you can talk

Day Three

SLEEP LOG (to be recorded the next morning)

What time did you lie down in bed last night:		Record time
What time did you try to go to sleep? (turned off light/put down phone)		Record time
About how long do you think it took you to fall asleep?		Record minutes
What time did you wake up this morning?		Record time
What time did you get out of bed this morning?		Record time

Day Four

Day of the Week ____________________ Participant ID: _________________________

During the day I removed the accelerometer:

Removal time ________ back on: _________ Reason ________________

Removal time ________ back on: _________ Reason ________________

Removal time ________ back on: _________ Reason ________________

Removal time ________ back on: _________ Reason ________________

Removal time ________ back on: _________ Reason ________________

Removal time ________ back on: _________ Reason ________________

During the day I did the following activity that might not have been recorded e.g swimming, biking or resistance activities (weights):

Description of Activity ____________ Time began: _____________ Time ended: ______

Intensity of activity: Light* ☐ Moderate** ☐ Vigorous*** ☐

Description of Activity ____________ Time began: _____________ Time ended: ______

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

Description of Activity ____________ Time began: _____________ Time ended: ______

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

*Activities which do not markedly increase heart rate of breathing rate

** Activities that elevate heart rate and breathing, but during which you can hold a conversation

***Activities that involve considerable exertion, and during which you are breathing so hard you can talk

Day Four

SLEEP LOG (to be recorded the next morning)

What time did you lie down in bed last night:		Record time
What time did you try to go to sleep? (turned off light/put down phone)		Record time
About how long do you think it took you to fall asleep?		Record minutes
What time did you wake up this morning?		Record time
What time did you get out of bed this morning?		Record time

Day Five

Day of the Week ______________________ Participant ID: ____________________________

During the day I removed the accelerometer:

Removal time ________ back on: __________ Reason _________________

Removal time ________ back on: __________ Reason _________________

Removal time ________ back on: __________ Reason _________________

Removal time ________ back on: __________ Reason _________________

Removal time ________ back on: __________ Reason _________________

Removal time ________ back on: __________ Reason _________________

During the day I did the following activity that might not have been recorded e.g swimming, biking or resistance activities (weights):

Description of Activity _____________ Time began: ______________ Time ended: _______

Intensity of activity: Light* ☐ Moderate** ☐ Vigorous*** ☐

Description of Activity _____________ Time began: ______________ Time ended: _______

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

Description of Activity _____________ Time began: ______________ Time ended: _______

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

*Activities which do not markedly increase heart rate of breathing rate

** Activities that elevate heart rate and breathing, but during which you can hold a conversation

***Activities that involve considerable exertion, and during which you are breathing so hard you can talk

Day Five

SLEEP LOG (to be recorded the next morning)

What time did you lie down in bed last night:		Record time
What time did you try to go to sleep? (turned off light/put down phone)		Record time
About how long do you think it took you to fall asleep?		Record minutes
What time did you wake up this morning?		Record time
What time did you get out of bed this morning?		Record time

Day Six

Day of the Week ______________________ Participant ID: ____________________________

During the day I removed the accelerometer:

Removal time _________ back on: ___________ Reason __________________

Removal time _________ back on: ___________ Reason __________________

Removal time _________ back on: ___________ Reason __________________

Removal time _________ back on: ___________ Reason __________________

Removal time _________ back on: ___________ Reason __________________

Removal time _________ back on: ___________ Reason __________________

During the day I did the following activity that might not have been recorded e.g swimming, biking or resistance activities (weights):

Description of Activity ______________ Time began: ______________ Time ended: _______

Intensity of activity: Light* ▯ Moderate** ▯ Vigorous*** ▯

Description of Activity ______________ Time began: ______________ Time ended: _______

Intensity of activity: Light ▯ Moderate ▯ Vigorous ▯

Description of Activity ______________ Time began: ______________ Time ended: _______

Intensity of activity: Light ▯ Moderate ▯ Vigorous ▯

*Activities which do not markedly increase heart rate of breathing rate

** Activities that elevate heart rate and breathing, but during which you can hold a conversation

***Activities that involve considerable exertion, and during which you are breathing so hard you can talk

Day Six

SLEEP LOG (to be recorded the next morning)

What time did you lie down in bed last night:		Record time
What time did you try to go to sleep? (turned off light/put down phone)		Record time
About how long do you think it took you to fall asleep?		Record minutes
What time did you wake up this morning?		Record time
What time did you get out of bed this morning?		Record time

Day Seven

Day of the Week ____________________ Participant ID: ____________________

During the day I removed the accelerometer:

Removal time ________ back on: ________ Reason ____________

Removal time ________ back on: ________ Reason ____________

Removal time ________ back on: ________ Reason ____________

Removal time ________ back on: ________ Reason ____________

Removal time ________ back on: ________ Reason ____________

Removal time ________ back on: ________ Reason ____________

During the day I did the following activity that might not have been recorded e.g swimming, biking or resistance activities (weights):

Description of Activity ____________ Time began: __________ Time ended: ______

Intensity of activity: Light* ☐ Moderate** ☐ Vigorous*** ☐

Description of Activity ____________ Time began: __________ Time ended: ______

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

Description of Activity ____________ Time began: __________ Time ended: ______

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

*Activities which do not markedly increase heart rate of breathing rate

** Activities that elevate heart rate and breathing, but during which you can hold a conversation

***Activities that involve considerable exertion, and during which you are breathing so hard you can talk

Day Seven

SLEEP LOG (to be recorded the next morning)

What time did you lie down in bed last night:		Record time
What time did you try to go to sleep? (turned off light/put down phone)		Record time
About how long do you think it took you to fall asleep?		Record minutes
What time did you wake up this morning?		Record time
What time did you get out of bed this morning?		Record time